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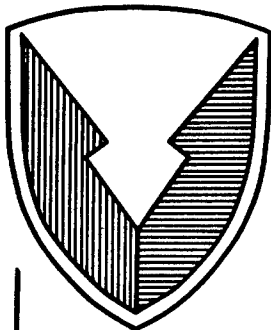
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Technical Report



No. 13549

SAFETY ASSESSMENT OF
TACOM'S CREW STATION/
TURRET MOTION BASE SIMULATOR

APRIL 1992

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REPORT DOCUMENTATION PAGE		1. REPORT NO.	2.	3. Recipient's Accession No.
4. Title and Subtitle SAFETY ASSESSMENT OF TACOM'S CREW STATION/TURRET MOTION BASE SIMULATOR (CS/TMBS)				5. Report Date April 1992
7. Author(s) Alexander A. Reid				6.
9. Performing Organization Name and Address U.S. Army Tank-Automotive Command ATTN: AMSTA-RYA Warren, MI 48397-5000				8. Performing Organization Rept. No. 13549
12. Sponsoring Organization Name and Address				10. Project/Task/Work Unit No.
				11. Contract(C) or Grant(G) No. (C) (G)
13. Type of Report & Period Covered FINAL				14.
15. Supplementary Notes				
16. Abstract (Limit: 200 words) This is a safety assessment of TACOM's Crew Station/Turret Motion Base Simulator. The report details the system description and hazard controls in an effort to satisfy requirements for a safety release from the U.S. Army Test and Evaluation Command.				
17. Document Analysis a. Descriptors Safety Assessment Report, Hazards b. Identifiers/Open-Ended Terms CS/TMBS, Simulators, Man-rating c. COSATI Field/Group				
18. Availability Statement		19. Security Class (This Report) Unclassified		21. No. of Pages 63
1		20. Security Class (This Page) Unclassified		22. Price

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SEPTEMBER 1991

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1.0. INTRODUCTION

The purpose of this Safety Assessment Report (SAR) is to provide the U.S. Army Test and Evaluation Command (TECOM) with the minimum protective measures, safety features and the specific safety procedural controls and precautions to be followed during use of the Crew Station/Turret Motion Base Simulator (CS/TMBS) located at the U.S. Army Tank-Automotive Command (TACOM) in Warren, Michigan.

The CS/TMBS was designed with a strong emphasis on safety for all involved personnel. Safety features are incorporated into both the hardware and software, and are listed in this manual as well as in the user's manual.

The safety features included in the CS/TMBS design consist of hazard controls in the form of hardware and software, which monitor position, rate and acceleration of the platform; power supplies; operator and user interfaces; oil pressure and temperature; and the software itself.

This simulator will be the second from TACOM to be safety certified by TECOM. In February, 1990, the Ride Motion Simulator received safety certification.

2.0. OBJECTIVE

The primary goal is to obtain a safety release from TECOM for the CS/TMBS. This safety release would cover the simulator itself and not include any crew station to be mounted upon the it. With the simulator certified as safe, any safety certified crew station could be mounted on the CS/TMBS. The proper safety shutdowns and communications established between the crew station and the CS/TMBS (as described in this report), TACOM would be ready to proceed with testing without needing a safety release for each test setup.

This report is issued in conjunction with TACOM Technical Report No. 13548, "SYSTEM HAZARD ANALYSIS OF TACOM's CREW STATION/TURRET MOTION BASE SIMULATOR," and is an attempt to satisfy MIL-STD-882B.

3.0. CONCLUSION

All known safety hazards have been evaluated throughout the design and development of the CS/TMBS. The system is considered safe to operate as long as the procedures stated in Contraves USA's Report No. IM-27751, "INSTRUCTION MANUAL FOR TACOM" are followed. The operating procedures are summed up in paragraph 5.4.

The safety devices and procedures for the CS/TMBS will reduce the probability of injury to occupant or damage to equipment to the levels dictated in MIL-STD-882B.

4.0. RECOMMENDATIONS

Upon issuance of a safety release for the CS/TMBS, it is suggested that the TACOM Safety Office be authorized to approve various test setups and crew stations, and issue safety releases for them.

5.0. DISCUSSION

5.1. Purpose and Intended Use

The CS/TMBS is a high performance six-axis motion simulator capable of handling payloads of up to 25 tons. It will recreate the dynamic motions a vehicle would experience traveling over cross country terrain while being capable of handling a wide range of crew stations from M1 turrets to smaller crew stations equipped with computer generated imagery systems.

The simulator is intended to replace costly field testing of vehicles in development (or being modified) with a controlled laboratory environment in which to conduct testing.

5.2. Background Information

The CS/TMBS is a six degree of freedom motion base simulator which will accommodate a turret weighing up to 25 tons. The CS/TMBS is considered a "Stewart Platform", named after the researcher who developed the concept in the late sixties. The basis of the Stewart Platform was developed for flight simulators and has been used for many applications in laboratory simulation. One feature which makes the CS/TMBS unique among the other known Stewart Platform systems is the capability to handle heavy loads with a bandwidth motion of 5 Hz.

The CS/TMBS was designed and built by Contraves USA and assembled jointly between Contraves USA and TACOM. All control compensation was performed by TACOM. The CS/TMBS is expected to open doors to new research, development and testing in the areas of gun/turret drive tracking and stabilization systems as well as man-in-the-loop testing. One potential feature of the CS/TMBS is the ability to test and study the soldier-machine interface while in a dynamic environment.

5.3 System Description

5.3.1. Structure. The CS/TMBS is a synergistic six degree-of-freedom motion base as shown in Figure 1. The test load mounting interface is provided on top of a rigid platform suspended above the base by six linear hydraulic actuators. The actuators are connected to the platform at three points and also to the base pads at three points. These points form the corners of an octahedron with triangular sides. This

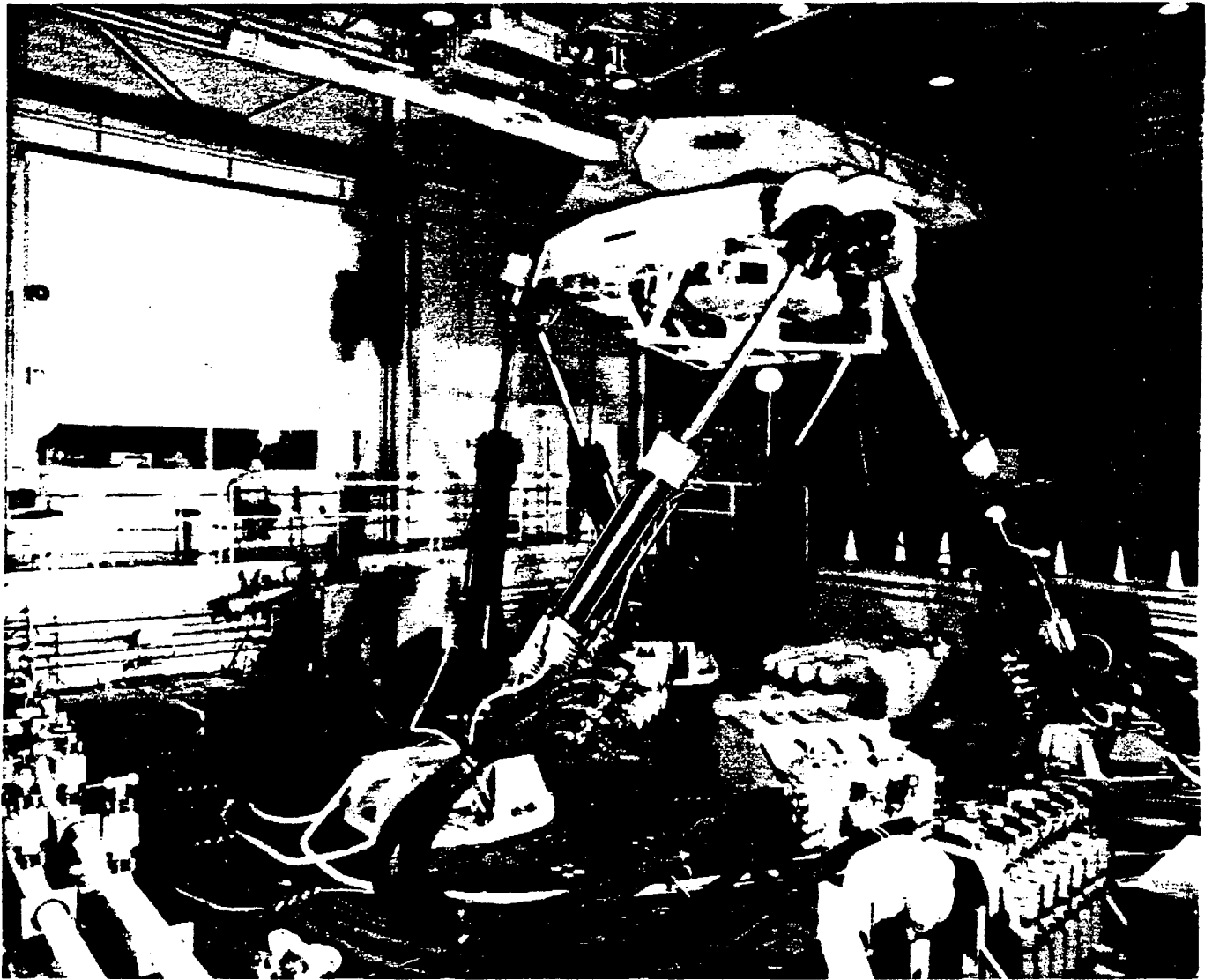


Figure 1. Crew Station/Turret Motion Base Simulator

required 6 degrees-of-freedom motion with the necessary dynamic configuration is the most efficient means of achieving the displacements.

5.3.1.1. Upper platform. The platform is made of steel plates welded together to form a stiff structure for support of various test loads. The first dynamic mode of the platform with swivel joints and actuators attached is greater than 70 Hz. Figure 2 shows the platform configuration.

5.3.1.2. Actuators. The actuator design consists of a linear cylinder, servo valve, position transducer, pressure transducers, limit switches, and associated valving.

The actuator utilizes laminar seals to minimize friction. The seals essentially eliminate coulomb friction and reduce the acceleration disturbance well below the requirement of 0.2 g's (See Table 1 for specifications).

5.3.1.3. Roller swivel joints. The roller swivel joint is constructed of 4340 steel shafts and tapered roller bearings. The bearings will support the 25 ton turret at 10 g's.

The upper swivel joint bearings are located in cast steel housings. The lower bearings are mounted in massive iron castings which are anchored to the T-bed.

5.3.1.4. Deceleration capability. The CS/TMBS is designed to stop with a 6 g maximum deceleration under all conditions. Deceleration is provided at both ends of the actuator travel by passive hydraulic cushions. The cushion is designed with a soft initial section followed by a stiffer section. This enables it to stop a lightweight turret or a heavy turret with 6 g's maximum deceleration. No adjustment is required.

5.3.1.5. Position/velocity sensor. The position/velocity sensor is a stainless steel probe installed within the hollow piston rod. A "donut" shaped magnet is installed in the piston. Using the magnetostrictive principle, a current pulse is sent from the sensing head along an inner nickel-cadmium wire. The magnet in the piston interacts with the current to cause a torsional stress in the wire. A torque sensor in the reading head detects the pulse. Timing electronics between the current pulse and torque pulse provide a position measurement (Figures 3 and 4).

5.3.1.6. Base assembly. The base consists of three identical assemblies as shown in Figure 5. Each unit consists of the lower mounting plate, filters, hydraulic manifolds, and associated hydraulic hose. Each base has mounting interfaces for the lower universal joint and the pier.

5.3.1.7. Electrical cables and hydraulic service. The system incorporates separate service connections for hydraulic and

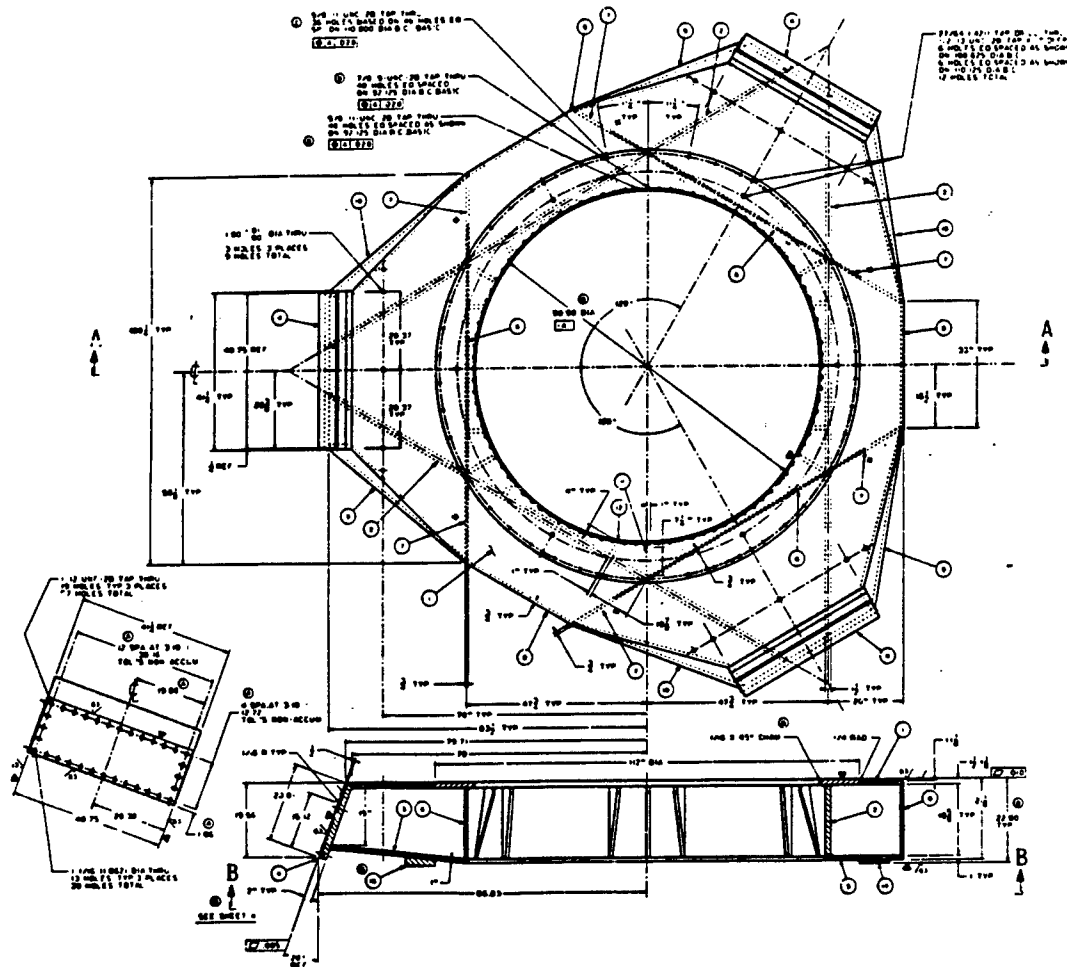


Table 1. Actuator Specifications

Characteristics	Value
Rod Diameter	5 in
Bore	7 in
Extension Force	115 klb
Retraction Force	56 klb
Extension Area	38.4 in ²
Retraction Area	18.9 in ²
Nominal Length (pin-pin)	13.33 ft
Stroke	+3.08/-2.92 ft
Displacement	11.6 gal
Average Speed at 167 gpm (1/6 of total pump flow)	1.9 ft/sec

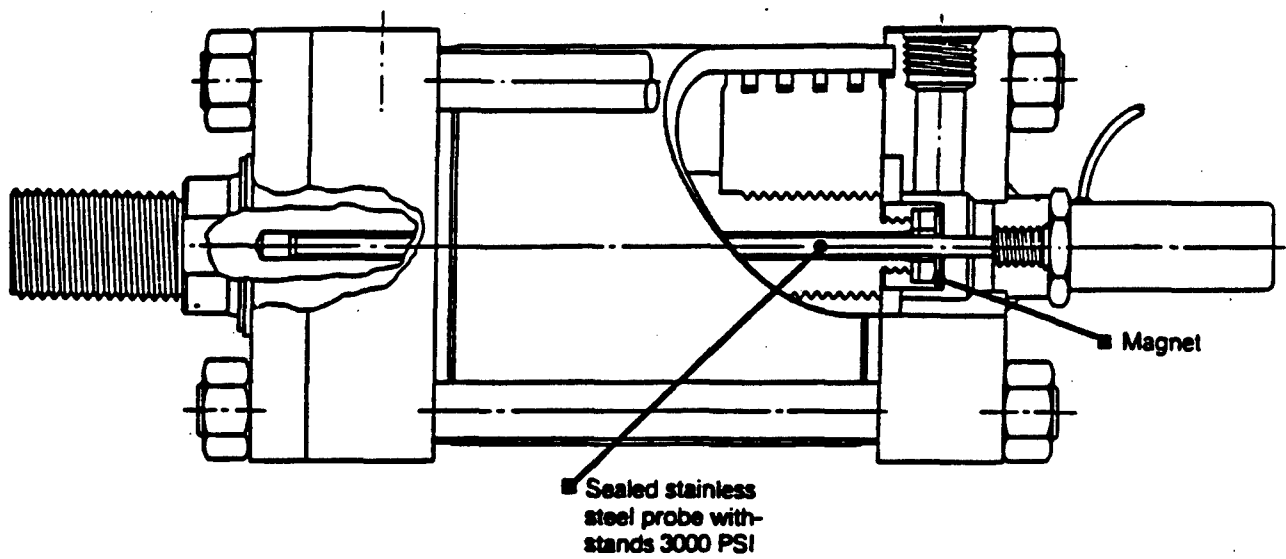


Figure 3. Position/Velocity Sensor Installation

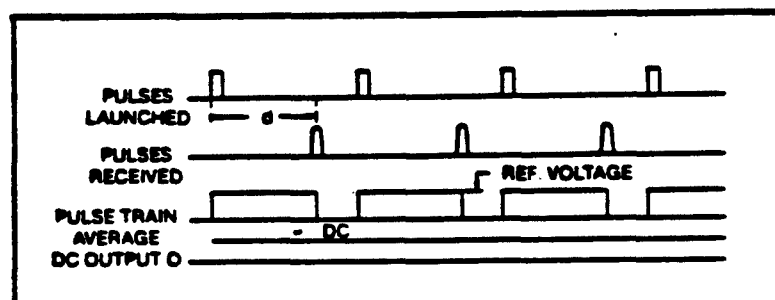


Figure 4. Position/Velocity Sensor

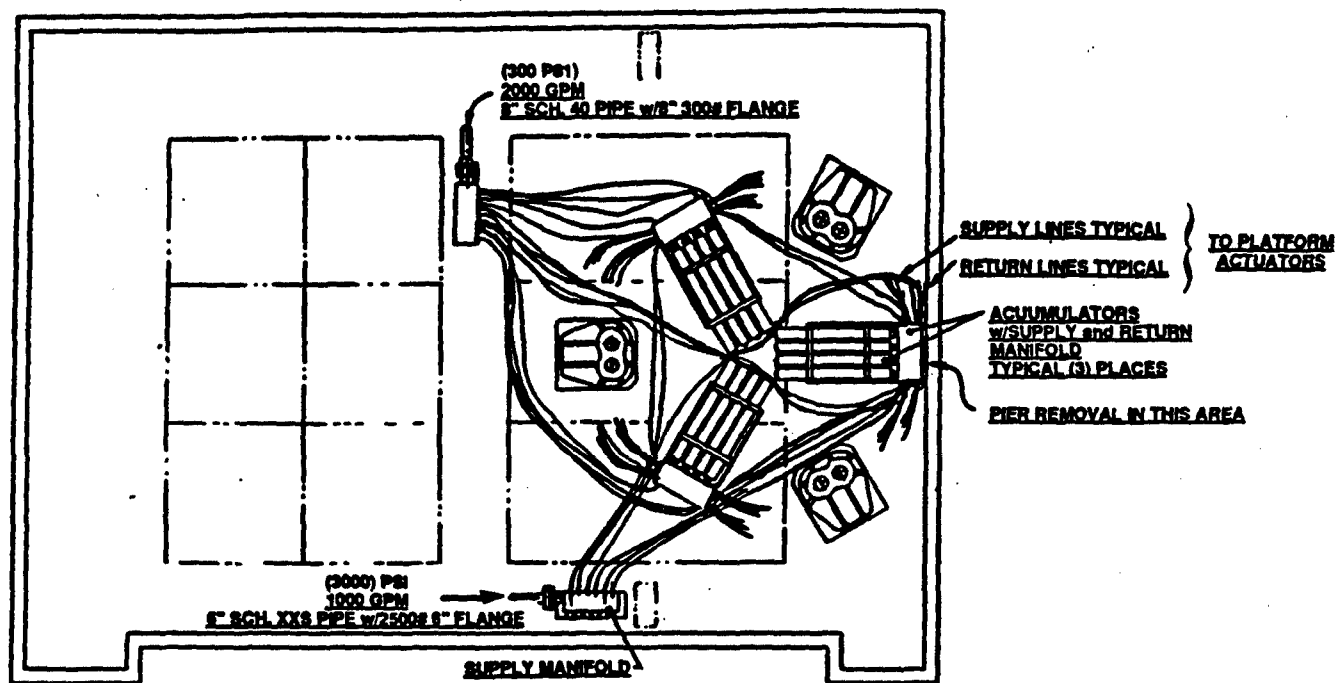


Figure 5. Hydraulic System View

electric service. All hydraulic services are run at pier level with manifolds at each of the three base assemblies. All electric service enters the simulator from the floor level to the platform via drape cabling. Special fixtures are provided to prevent overstress or excessive bending of the cabling.

5.3.1.8. Actuator hydraulic circuit. The actuator hydraulic circuit features:

- Three servo valves for primary control of the actuator.
- A settling valve to control settling during shutdown conditions.
- Abort valves -- used to isolate the servo valves during startup and shutdown.
- Crossport damping valve to introduce damping flow across the actuator piston.
- Electrically selectable dual setting relief valves. High pressure for operation and low pressure braking in case of abort.
- Pressure transducers to monitor the control pressures.

5.3.2. Hydraulic System. The CS/TMBS hydraulic system consists of six major components (See Figure 6): a supply manifold (Figure 7); a return manifold (Figure 8), a hydraulic power supply (HPS); and a three accumulator manifold (Figure 9).

5.3.2.1. Supply manifold. The supply manifold receives 3000 psi of oil from the hydraulic power supply via a high pressure 150 mm line. The oil is divided into six separate legs. Each leg passes through a manual 50 mm ball valve, a 180 gpm Hycon filter (5 micron), and an electrically operated cartridge valve. Two legs are then connected to each accumulator manifold via 50 mm hoses.

5.3.2.2. Accumulator manifold. The three accumulator manifolds are located on the floor beneath the motion platform. They are kept close to the actuators to minimize acceleration losses in the supply and return lines. Each manifold feeds two actuators via three 50 mm supply and three 50 mm return hoses. High pressure oil from the supply manifold is fed into six 5000 psi rated accumulators on each manifold. Five are used during simulation while one is held in reserve for emergency actuator retraction. Two 3000 psi rated accumulators per manifold are connected to the low pressure return system and act as surge suppressors. This allows the HPS to be located up to 200 ft

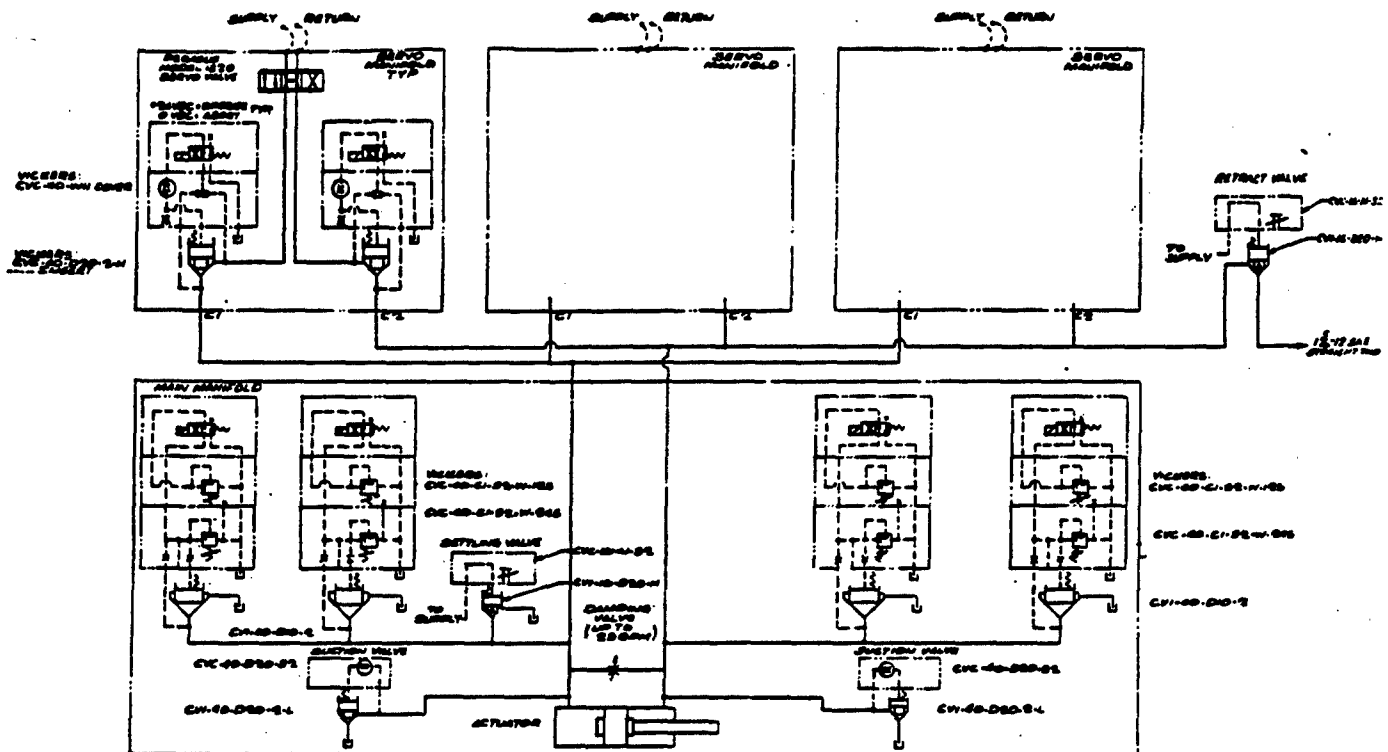


Figure 6. Cylinder Hydraulic Schematic

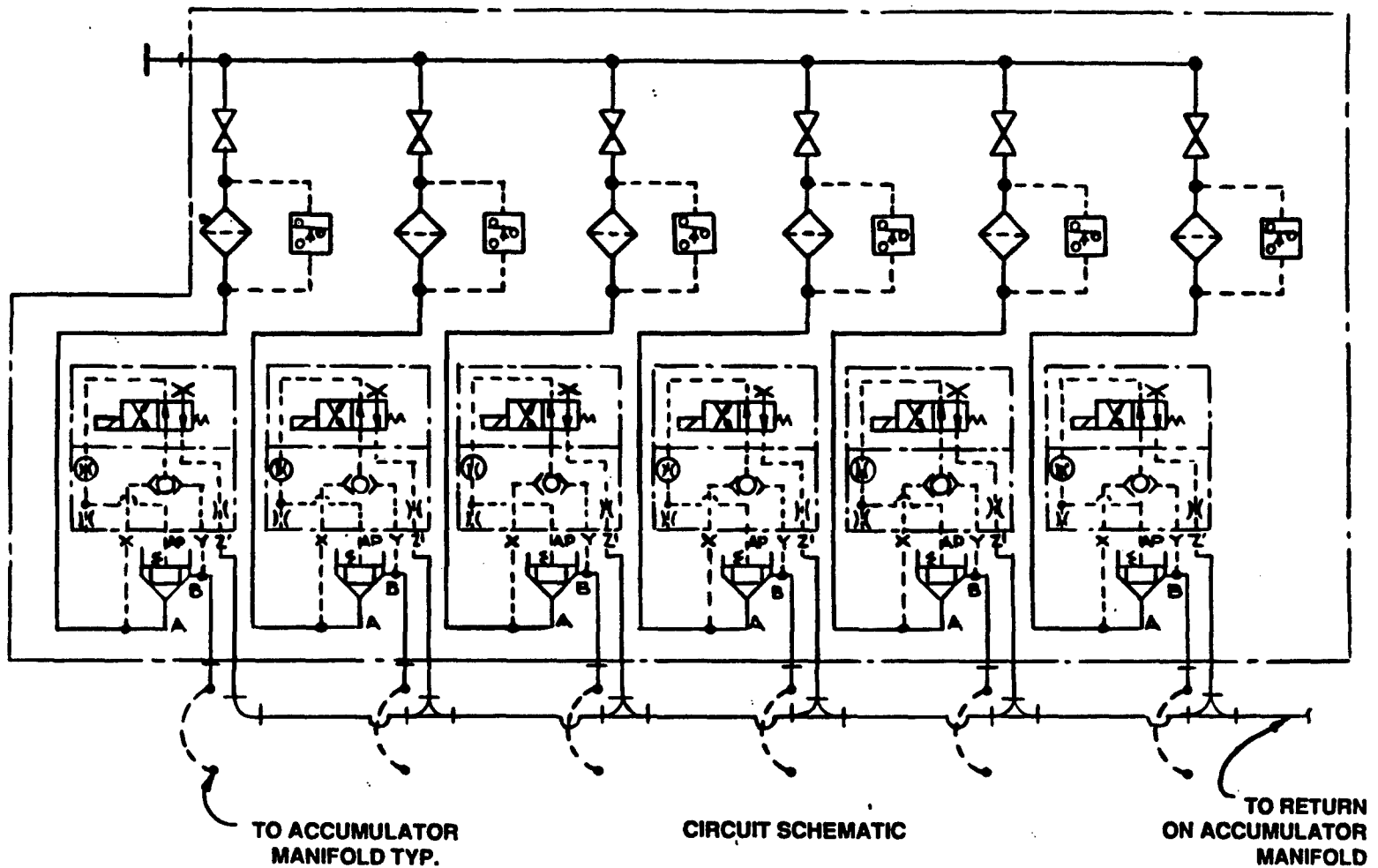


Figure 7. Supply Manifold Schematic

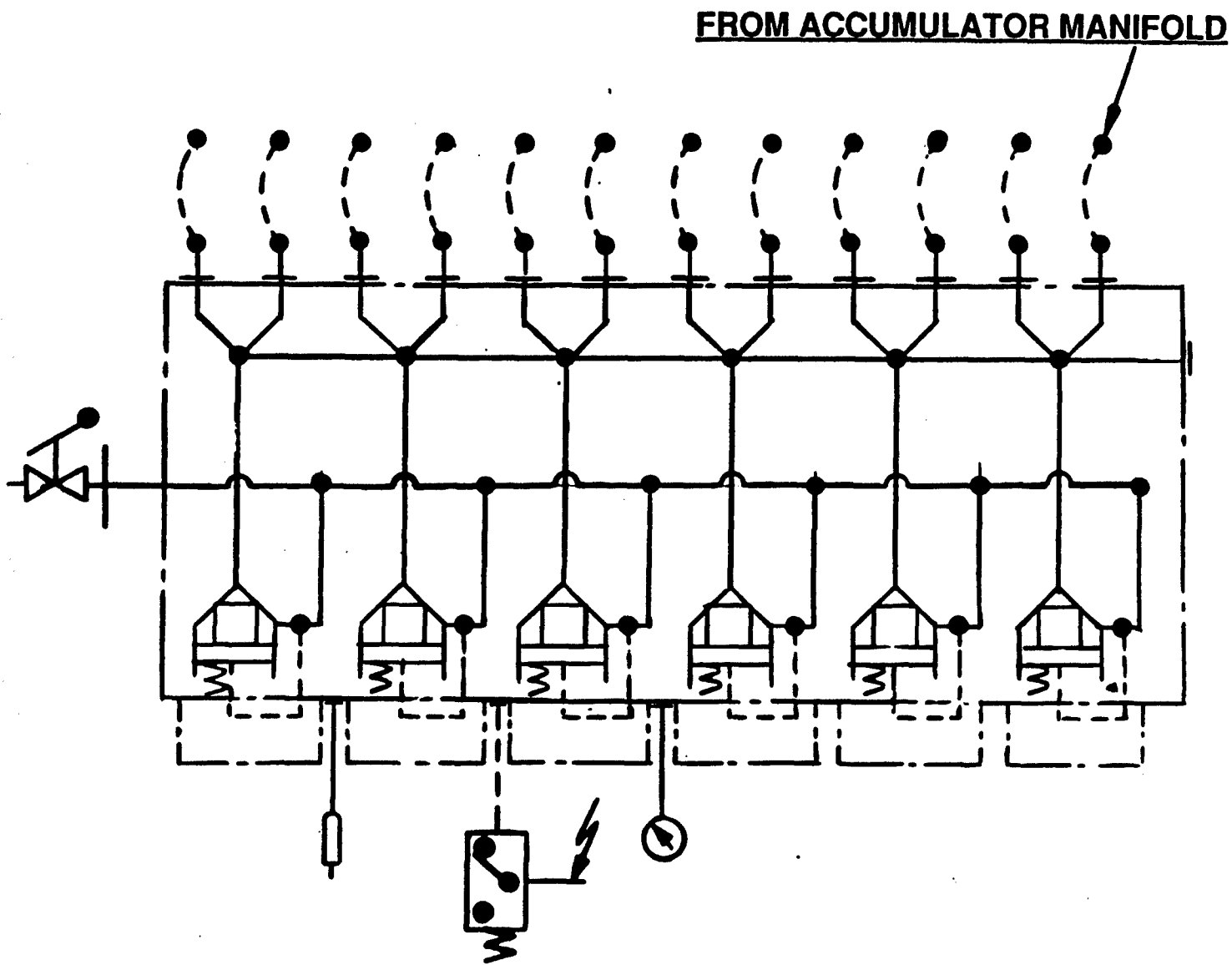


Figure 8. Return Manifold Schematic

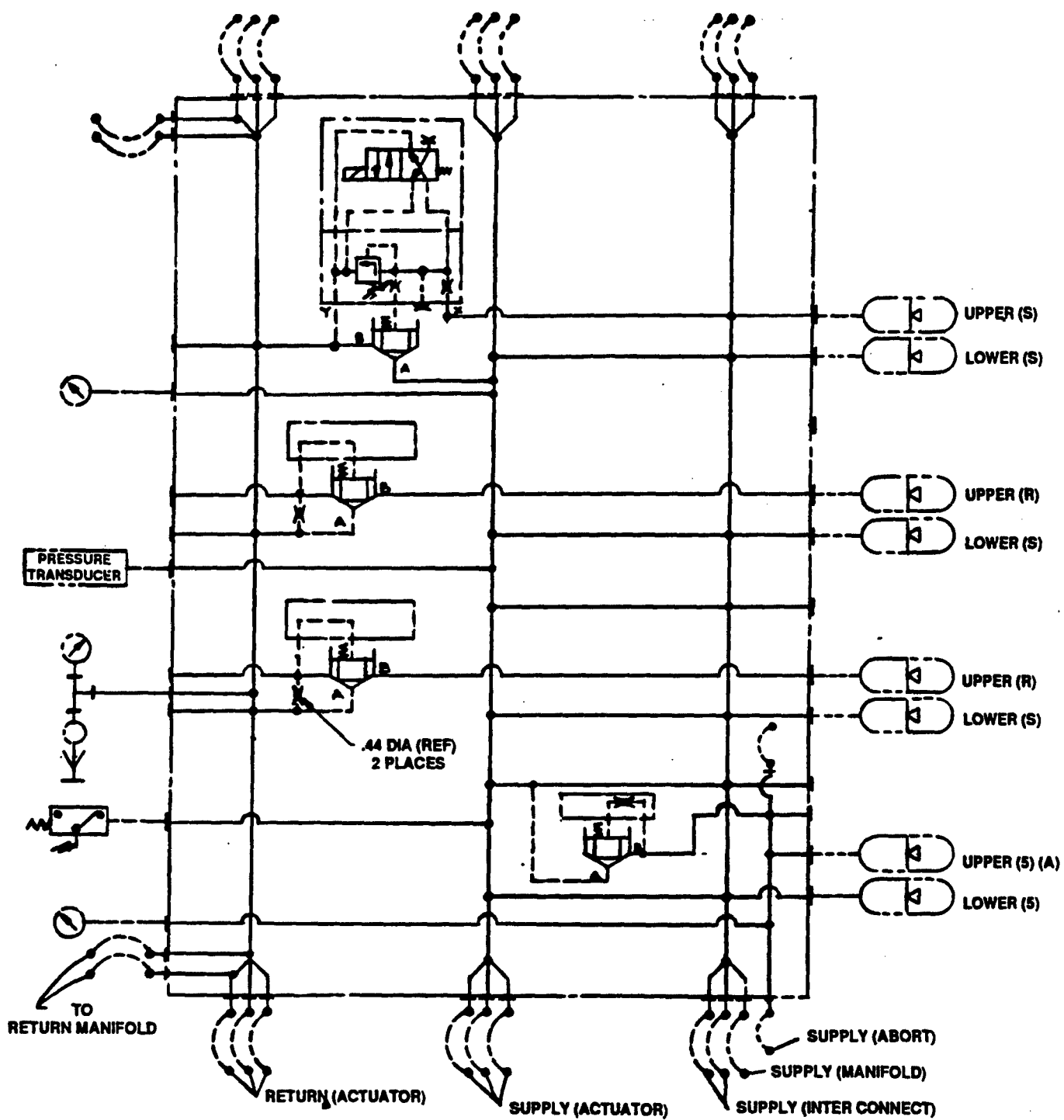


Figure 9. Accumulator Manifold Schematic

away from the motion base. The three accumulator manifold supply circuits are interconnected in a delta configuration with two 50 mm hoses connecting each to the other two. This maintains equal supply pressures.

5.3.2.3. Return manifold. Four 50 mm hoses from each accumulator manifold are connected to the return manifold. The oil passes through six check valves and is collected into a single 200 mm line. The manifold is connected to a 200 mm, 300 psi, 2000 gpm return line which carries the oil back to the HPS reservoir. A 200 mm butterfly valve is provided at the manifold connection for maintenance purposes.

5.3.2.4. Hydraulic power supply (HPS). The hydraulic power supply has a reservoir of 2150 gallons and is capable of supplying 1000 gpm at a pressure of 3000 psi.

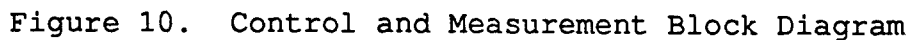
5.3.3. Control/Measurement System. The CS/TMBS Control/Measurement System includes six major elements:

- Control Console and Subsystems
- Transducer Amplifier Box
- Interlock Control Box
- Actuator Instrumentation
- Hydraulic Instrumentation
- Inertial Measurement Unit

Figure 10 shows the main components of the Control/Measurement System that are described in the following sections.

5.3.3.1. Control console (Figure 11). The control console is a three-bay sloped panel wrap-around console from which the system operator controls all aspects of the system operation. The console is designed in accordance to MIL-STD-1472C for ease of operation. The primary consideration in the design of the console, associated electronics and software is the safety of personnel and equipment.

System startup and major modes of operation are controlled by a combination of push-button and key-lock switches. Linear slide potentiometers permit manual control of the system in Maintenance mode. Functions that are not as safety critical are controlled from the CRT terminal. To prevent unauthorized use, the system operator must enter a password before critical system parameters can be changed. Status indicators on the Operator Panel give the operator an overview of the system status. Details of system status are provided on the computer CRT.



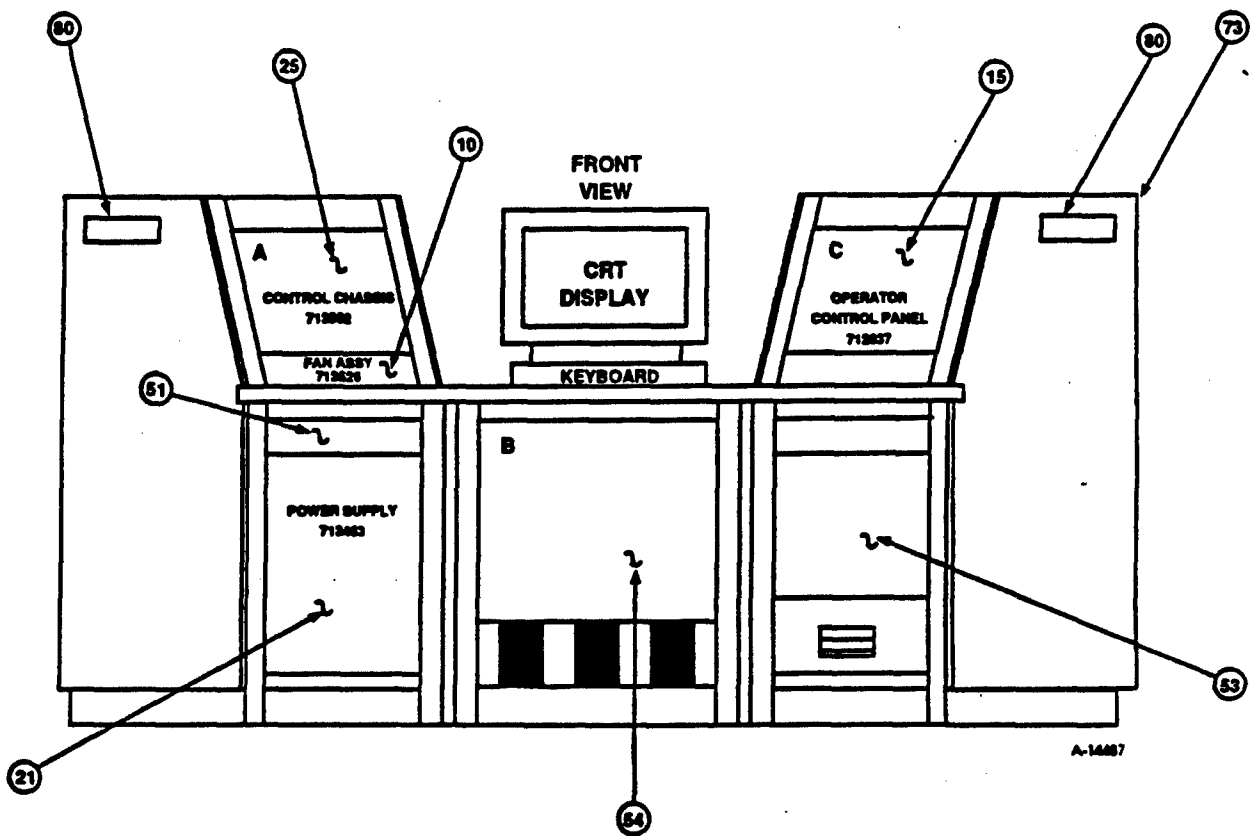


Figure 11. Control Console

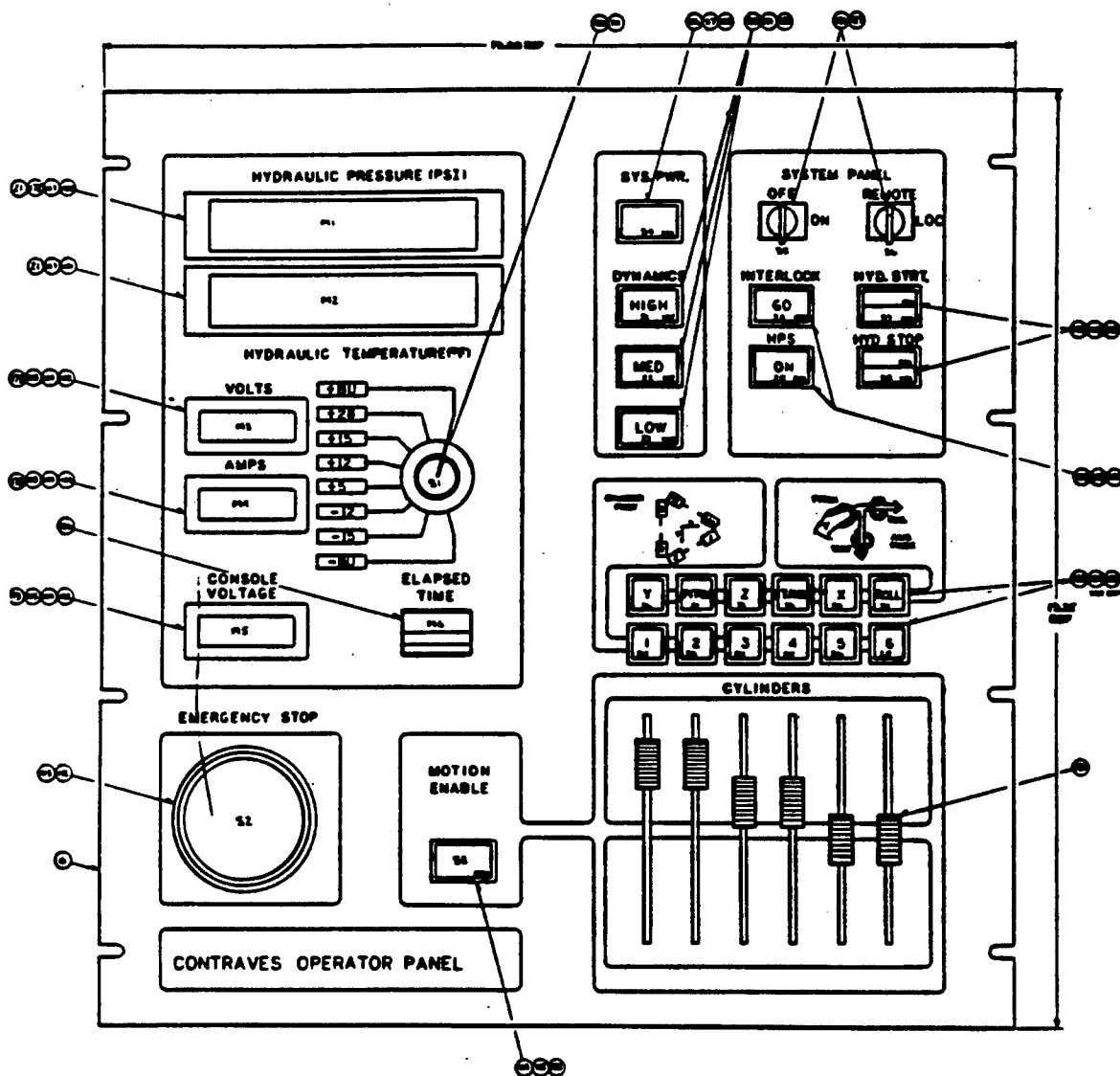


Figure 12. Operator Panel

5.3.3.1.1. Operator panel (Figure 12). The operator panel contains the primary switches and displays to control and monitor the system operation. The following indicators provide overall system status:

- Low/Med/High Dynamic indicators
- Interlock GO indicator
- HPS ON indicator
- Axis mode indicates: Y, Pitch, Z, Yaw, X, Roll
- Cylinder mode indicators: Cyl 1, 2, 3, 4, 5, and 6

The following switches control the system and determine the major modes of operation:

- System Power ON/OFF switch
- System ON/OFF keyswitch
- Remote/Local keyswitch
- Hydraulic Start (momentary pushbutton)
- Hydraulic Stop (momentary pushbutton)
- Motion Enable (momentary pushbutton)
- Emergency Stop (momentary pushbutton)

Metered indicators are provided to assist in maintenance and troubleshooting:

- Hydraulic Pressure (LED bar graph)
- Hydraulic Temperature (LED bar graph)
- Power Supply Voltage (digital voltmeter)
- Power Supply Current (digital ammeter)
- Console Voltage (digital voltmeter)
- Elapsed Timer Meter

The operator panel is also used to provide manual control of the CS/TMBS in Maintenance mode. The maintenance panel allows two manual modes of operation: Axis mode and Cylinder mode.

- Axis mode allows the operator to position the simulator in each of the six degrees of freedom: X, Y, Z, roll, pitch, and yaw.
- Cylinder mode allows the operator to independently control the extension of each of the six hydraulic actuators.

The selection of axis or cylinder mode is made from the console CRT terminal. Indicators associated with the slide potentiometers display what axis or cylinder motion will result from movement of the controls. It is also possible to control system motion from the keyboard instead of the potentiometers.

A momentary action Motion Enable pushbutton prevents the simulator from moving when the button is not depressed.

5.3.3.1.2. Control chassis (Figure 13). The control chassis contains the CS/TMBS system control electronics including all system computer and computer interfaces. The chassis is a Multibus I card cage in which the following circuit boards reside:

- AD-100 Interface Card
- Supervisor Single Board Computer
- Array Processor Card Set (3 boards)
- Safety Monitor Single Board Computer
- Encoder Servo Processor (6 ESP boards)
- A/D Converter Single Board Computer (1)
- D/A Converter Card (3)

The connector panel attached to the rear of the card cage allows for easy installation and removal of this assembly.

5.3.3.1.3. CRT terminal. The CRT terminal is the main operator interface to the system computers located in the control chassis. The unit is a Digital Equipment Corporation Model VT-341 color display terminal.

5.3.3.1.4. Inertial Measurement Unit (IMU) chassis. The IMU chassis provides the control and signal conditioning electronics for the IMU located on the CS/TMBS. This chassis contains three printed circuit boards:

- Linear acceleration signal conditioning board.
- Angular acceleration signal conditioning board.

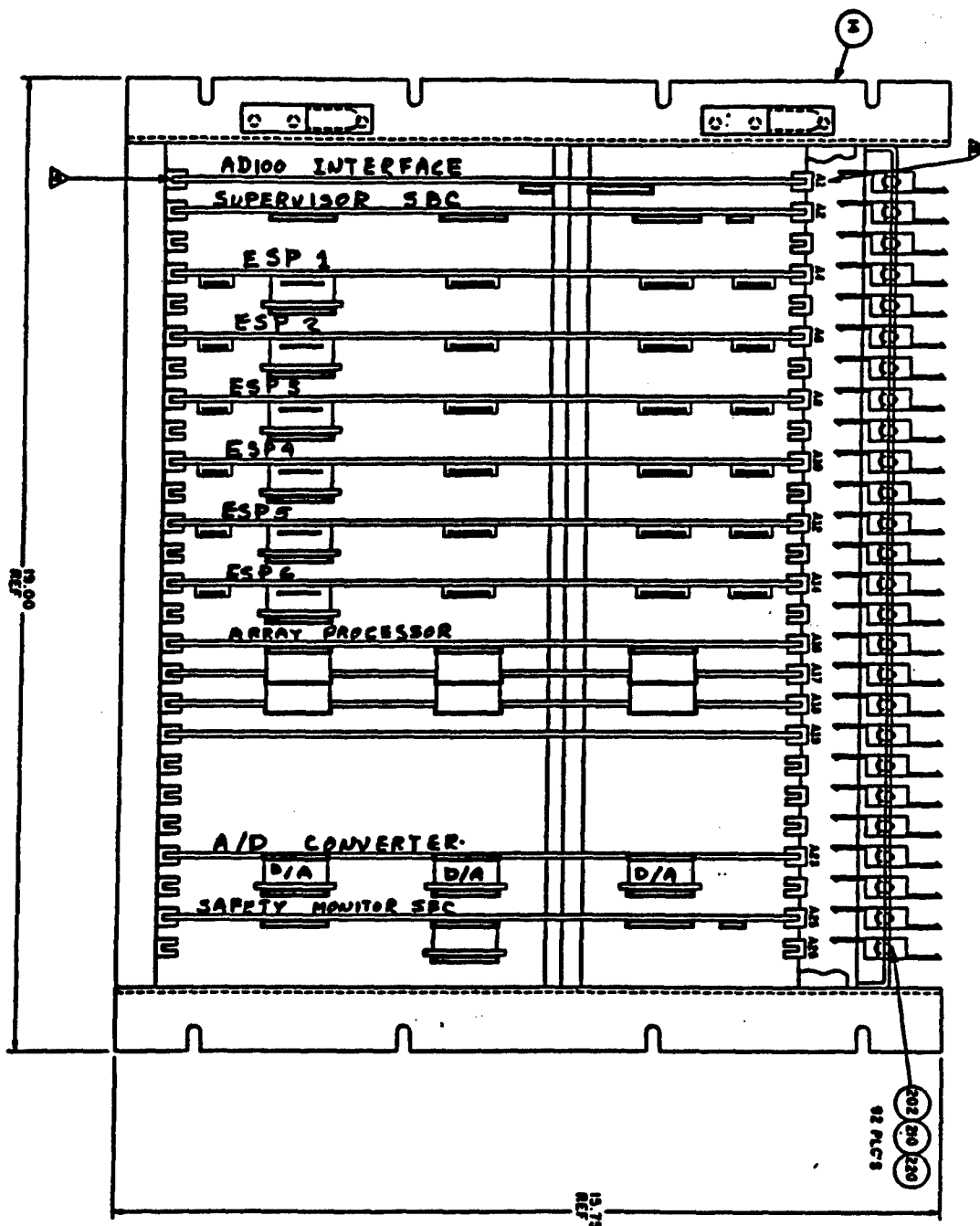


Figure 13. Control Chassis

o Angular rate signal conditioning board.

The IMU electronics synthesizes three-axis angular and linear accelerations from the sums and differences of eight linear accelerometers. These accelerometers are located in four accelerometer packages mounted on the platform equidistant from the turret axis and 90 degrees apart from each other. This permits direct measurement of acceleration within the turret crew compartment for inclusion in the hardware safety interlock system.

The linear acceleration signal conditioning board has analog circuits that produce a signal proportional to the square root of the sum-of-the-squares of the three orthogonal axis signals. This signal represents the composite magnitude of linear acceleration. If this signal exceeds a preset limit proportional to the maximum allowable acceleration, a signal to the Interlock Chassis will cause the hydraulic system to abort. Similar circuitry will cause an abort if an angular acceleration limit is exceeded.

Before the hydraulics can be enabled, a self-test signal from the Interlock Chassis is applied to the eight linear accelerometers through self-test electronics. The safety monitor computer compares the digitized outputs from the IMU chassis with known limits to determine that the accelerometers and signal conditioning electronics are functioning properly.

A three-axis integrating rate gyro, mounted on one of the principal axis of the platform, provides an output proportional to angular rate. The angular rate signal conditioning board also generates a magnitude signal that is tied to the safety interlock system.

The IMU chassis produces twelve analog signals:

- o X Acceleration
- o Y Acceleration
- o Z Acceleration
- o Linear Acceleration Magnitude
- o Yaw Acceleration
- o Pitch Acceleration
- o Roll Acceleration
- o Angular Acceleration Magnitude
- o Yaw Rate

- Pitch Rate
- Roll Rate
- Angular Rate Magnitude

These signals are digitized in the Control Chassis and are also available for monitoring on BNC connectors located on the rear panel of the IMU chassis.

5.3.3.1.5. Interlock chassis. The Interlock chassis serves two functions in the CS/TMBS system:

- Hardware interlock string to control the system hydraulic supply and to abort system independent of the computer controls.
- Status input and control output for the computer control system.

The hardware interlock string connects to safety critical sensors, insuring that the simulator ceases motion in the event of hardware or software malfunction. The interlock string is implemented with solid state logic and reed relays to provide the fast response required to abort the system and limit accelerations to less than 4 G's for less than 40 milliseconds. Certain elements of the hardware interlock string are necessarily bypassed at system start-up to allow the simulator and hydraulics to reach normal operating status. These conditional bypasses are terminated by events and/or time delays.

- Interlock Card (4) - These cards have 16 opto-isolated inputs that can be connected to contact closures or TTL signals. All input transitions are latched and their status can be read by the Safety Monitor Computer. Through jumpers and chassis wiring, groups of inputs can be connected to the hardware interlock string or can be used for computer status only. (Interlock inputs can also be configured in such a way that they are bypassed until after a time delay initiated by an external event.) This feature is required because certain interlock conditions (e.g., cylinder retract limits) will not be satisfied at the time of system start-up.
- Analog Limit Card (6) - Each of these cards has eight differential analog input channels. Each input has independent high limit and low limit potentiometers associated with it to set over- and under-voltage limits. The status of the 16 limits is latched and can be read by the Safety Monitor

Computer. This basic configuration is used to test and interlock absolute high and low limits for power supplies, force transducers, etc. Factory select components can be used to low-pass filter the inputs as well as set a minimum fault duration for noise and transient immunity. Each channel also has an associated auxiliary input that allows it to operate as a tracking comparator. In this mode, two input voltages must follow each other within limits to maintain the interlock. This mode is used to compare servo valve spool position with servo valve command, etc. As with the Interlock Card, groups of channels can be configured into the interlock string or used as status only to the Safety Monitor Computer. These groups can also be configured with the bypass-delay feature.

- Control and Status Card (3) - This card has 16 output channels and 16 input channels. The output channels are latched peripheral drivers capable of switching 300 mADC for lamps, relay coils, solenoids, and solid-state relays. The input channels are comparators with a 1.5 volt threshold. The inputs can be connected to TTL, open collector signals or contact closures. Inputs can be configured to monitor lamp filaments on output channels, allowing for automatic computer controlled lamp test. Each card also has several non-dedicated relays that can be used to switch AC voltages or perform miscellaneous interlock functions.

5.3.3.1.6. I/O Panel (Figure 14). The I/O panel contains the following:

- 24 System Analog Outputs
- 6 System Analog Inputs
- 12 ESP Analog Outputs (2 each)
- 6 ESP Digital Outputs (1 each)
- 6 ESP Analog Inputs
- 3 RS-232 connectors
- 6 Line Voltage Convenience Outlets

The System Analog Outputs are connected to the D/A converter cards in the Control Chassis. These are used as system test points and the function of each is software selectable. They can output both internal system variables as well as digitized voltages.

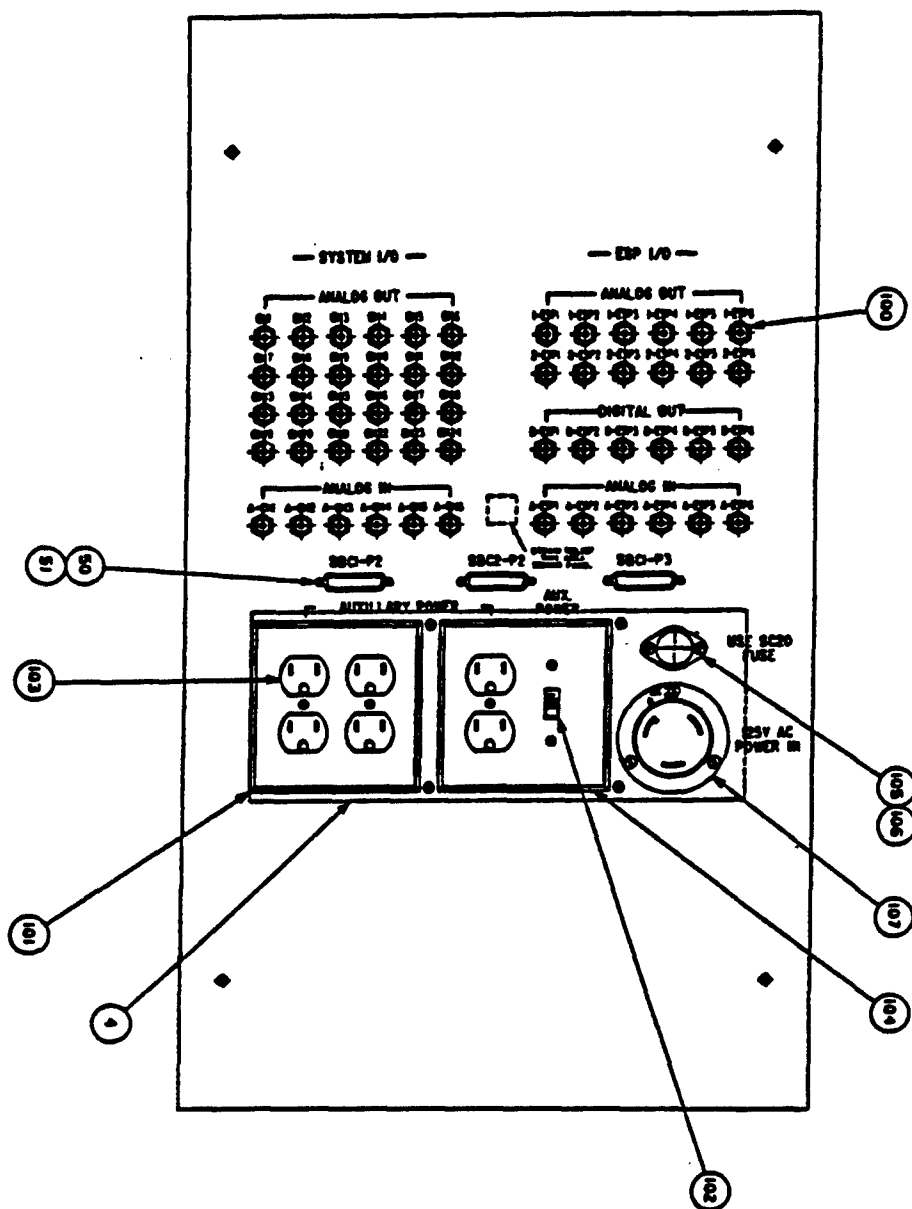


Figure 14. I/O Panel

The System Analog Inputs are used in certain test modes to control the platform in cylinder mode or axis mode.

The ESP Analog Outputs are software selectable to output internal ESP variables. These signals come from two D/A channels on each ESP board.

The ESP Digital Outputs are used in certain test modes to output event markers.

The ESP Analog Inputs are used in certain test modes to control the ESP operation from an external analog voltage.

One of the RS-232 connectors attaches to the console CRT terminal. The other two connectors go to the single board computers for test and software debug.

The auxiliary power convenience outlets are to provide power for the CRT terminal and test equipment when required.

5.3.3.1.7. Power Supply Chassis. The Power Supply Chassis provides DC power for all of the control electronics in the console. It contains the following:

- +5 volt, 120A supply
- +15 volt, 9A supply
- +15 volt, 9A backup supply
- -15 volt, 9A supply
- -15 volt, 9A backup supply
- ±12 volt, 3.4A supply
- +28 volt, 3A supply
- AC Line Voltage Monitor

The 5-volt supply provides power for all of the system's digital electronics and the ±15-volt supplies provide power for the analog circuits. The 15 volt backup supply maintains analog voltages in case of the failure of one of the primary supplies. The ±12-volt supply is used for the RS-232 links, as well as the Temposonics position transducers. The ±12-volt supply is reinforced by the 15-volt supply by means of a diode voltage drop arrangement. The 28-volt supply is used by the IMU rate integrating gyro. All supply outputs have current sense resistors for the Operator Panel current monitor. The system is designed so that all supplies have greater than 25% excess capacity.

The Power Supply Chassis has two front panel indicators; Standby and On. The Standby lamp indicates that the chassis has AC power at its input, but the power supply is not turned on. The power ON switch at the Operator Panel activates a contact in the Power Supply Chassis, switching from Standby to On mode. The power ON switch is interlocked with the system hydraulic pressure switch so that the electronics can not be turned off while the system hydraulics is on.

5.3.3.2. Transducer Amplifier Box (Figure 15). The Transducer Amplifier Box is a Nema enclosure located adjacent to the CS/TMBS. This enclosure contains three card racks of Moog servo valve electronics. The Moog electronics closes the servo valve position loops for the 18 system servo valves (three per actuator). The electronics is grouped for safety reasons so that a power supply failure in one of the Moog card racks causes the failure of six servo valves located symmetrically around the CS/TMBS platform. The remaining 12 servo valves will maintain stability until the system aborts. This enclosure also houses the strain gauge amplifiers for the actuator force sensors as well as the differential pressure summing circuits used to derive force from actuator pressures. The differential pressure electronics applies different gains to the extend and retract pressure transducer signals. This is to compensate for the different areas on each side of the piston. The difference of these two resultant signals is proportional to force.

5.3.3.3. Interlock Control Box (Figure 16). The Interlock Control Box is a Nema enclosure located adjacent to the CS/TMBS. This enclosure contains the solid state relays used to switch the 24 volt AC hydraulic solenoid valves for the CS/TMBS. Twelve solid state relays control the following solenoid valves:

- 36 servo shutoff valves (6 per actuator)
- 24 abort valves (4 per actuator)
- 6 system supply valves
- 3 accumulator relief valves (1 per manifold)

The solenoid valves are grouped with the solid-state relays so that a solid-state relay (SSR) failure will affect only three solenoid valves located symmetrically about the CS/TMBS platform. This assures that the platform will remain level during the abort process. Each group of six solenoid valves of identical function is driven by a pair of solid-state relays. If the outputs of the pair are not the same due to an open fuse or relay failure, an SSR fault relay closes, thereby initiating the abort process.

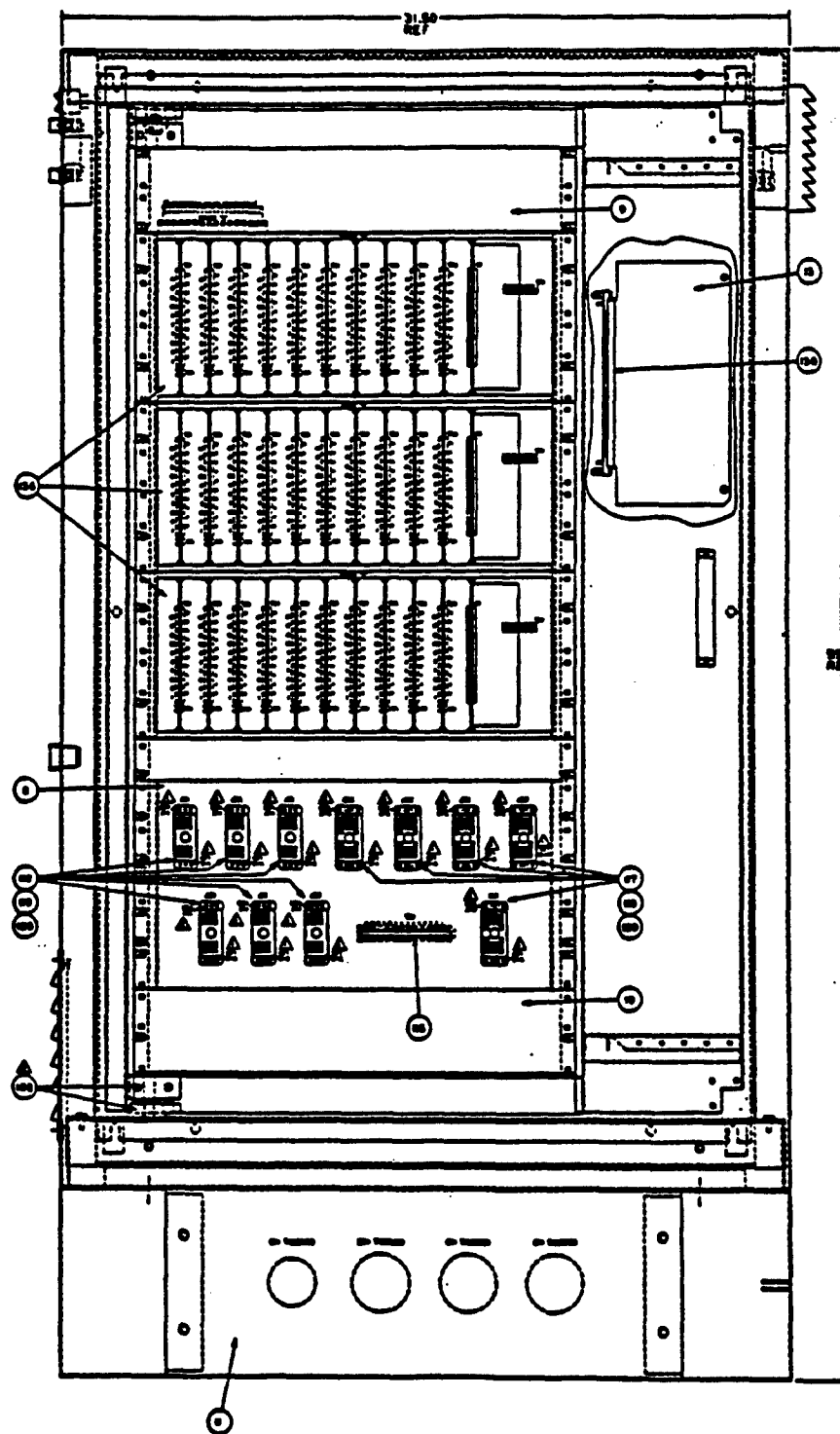


Figure 15. Transducer Amplifier Box

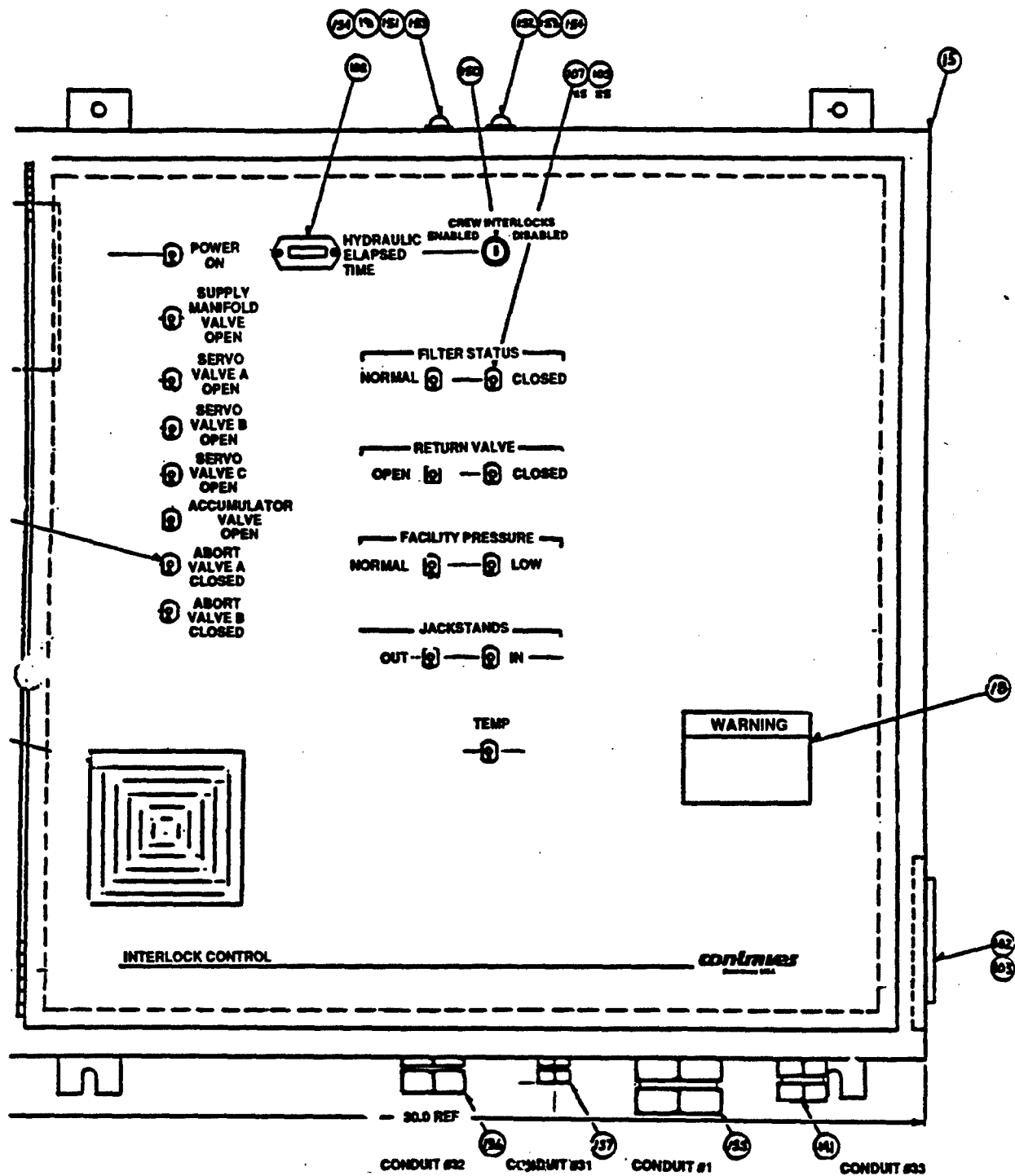


Figure 16. Interlock Control Box

The Interlock Control Box has a Crew Enable/Disable keyswitch on the front panel. In the Disable mode, the crew compartment interlocks are bypassed so the simulator can be used without personnel in the crew compartment. In the Enable mode, the Inertial Switch, Motion Consent, Crew Emergency Stop, and Deadman switch are active. (The key can be removed in the Enable mode in order for the crew to insert it in a keyswitch, which is located in the crew compartment. This completes the Motion Enable interlock prior to system start-up.) A green indicator on the top of the enclosure indicates "Crew Enable" and an amber indicator shows "Crew Disable".

Six switches located inside the Interlock Control Box allow individual actuators to be enabled or disabled for maintenance and integration. In the disable mode, the retract limit interlock is satisfied unless the actuator moves out of the retract limit. Special maintenance software has to be used to run the system with the actuator disabled. The following indicators show the hydraulic and actuator status:

- Filter Clogged/Normal
- Return Valve Open/Closed
- Facility Pressure Normal/Low
- Jackstands In/Out
- Temperature High (Enclosure)
- Supply Manifold Valve Open
- Servo Valve A Open
- Servo Valve B Open
- Servo Valve C Open
- Accumulator (relief) Valve Open

A computer controlled warning horn is built into the enclosure's front door to warn personnel that the hydraulics is about to be activated and to signal a system abort.

5.3.3.4. Actuator instrumentation (Figure 17). The following instrumentation is associated with each hydraulic actuator:

- Three servo valves with LVDT spool position transducers
- Temposonics linear position transducer
- Strain gauge force sensor

- Two pressure transducers (extend and retract)
- Six servo shutoff solenoid valves (two per servo valve)
- Two extend abort solenoid valves
- Two retract abort solenoid valves
- Two limit switches (extend and retract)

All actuator sensors are integrated into the actuator package and the sensor electronics are provided in the Transducer Amplifier Box near the platform base.

5.3.3.5. Hydraulic instrumentation (Figure 18). In addition to the hydraulic instrumentation on each actuator, the following system level instrumentation is provided to control and monitor the hydraulics and to ensure safe operation:

- System Pressure Transducer (analog)
- Oil Temperature Transducer (analog)
- Facility Pressure Switch
- Pressure Critical Switch
- Six Supply Solenoid Valves
- Three Accumulator Relief Solenoid Valves
- Return Pressure Switch
- Return Valve Switch
- Six Filter Clogged Switches (one per filter)

The Facility Pressure switch detects pressure (>2000 psi) on the supply side of the supply manifold. The supply solenoid valves (also on the supply manifold) isolate the CS/TMBS system from the Hydraulic Power Supply unless the system is operational. The oil filters and Filter Clogged switches are also on the supply manifold.

The three accumulator manifolds beneath the platform each have an Accumulator Relief valve that discharges accumulator oil to the reservoir in an abort condition. A reserve accumulator not used during system operation discharges a controlled flow through the actuators when the system aborts. This flow forces the actuators to the retract position and the actuator abort valves assure that the retract pressure is not excessive. The analog system pressure transducer is located on accumulator

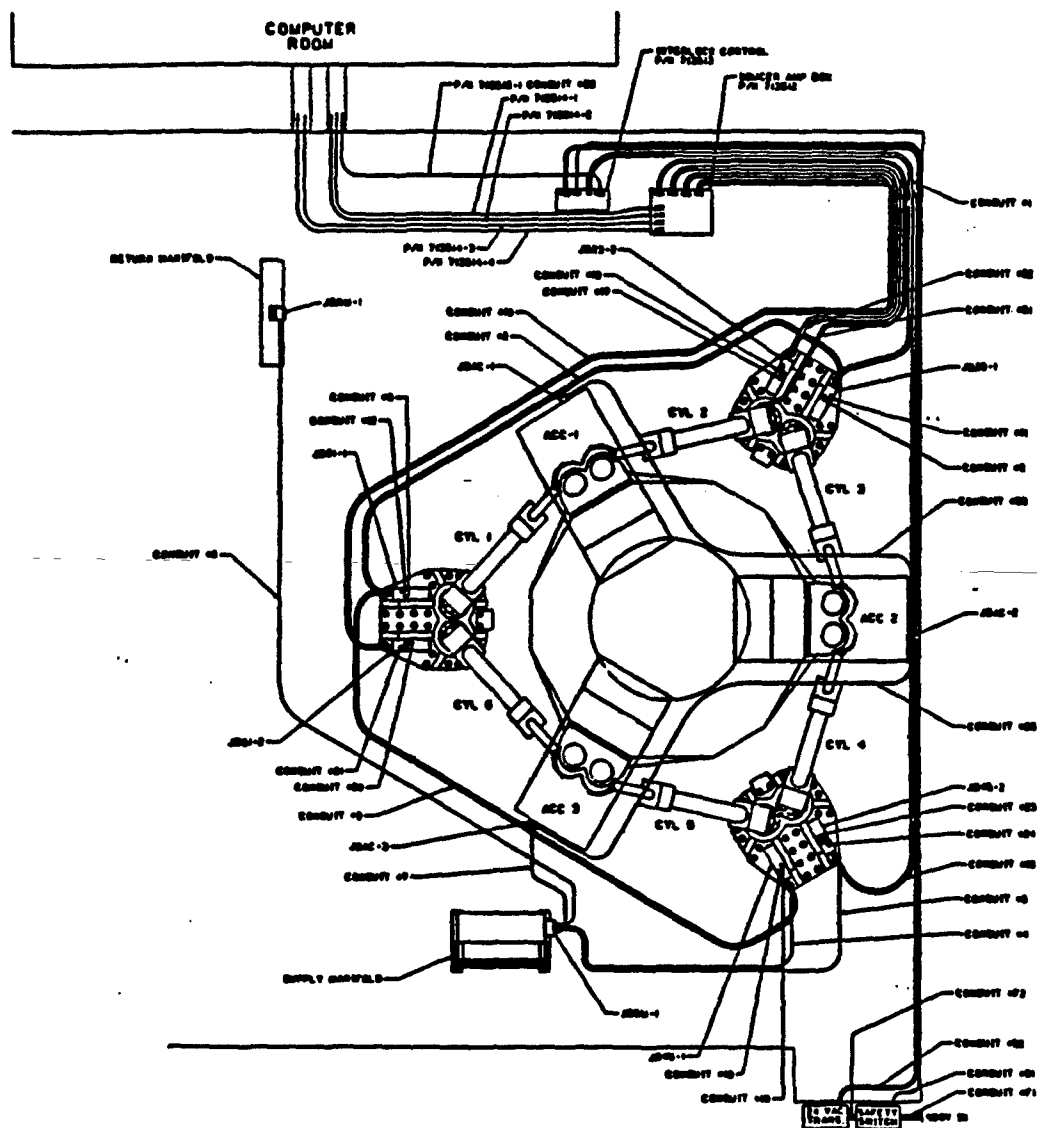


Figure 18. Simulator Electrical View

manifold #3. The pressure Critical switch (also on manifold #3) aborts the system when the pressure drops to less than 1500 psi (the pressure required to maintain equilibrium).

The Return Pressure switch and Return Valve switch are located on the return manifold to assure that the system cannot be operated with the return valve closed. The oil temperature transducer is also located on this manifold.

5.3.3.6. Inertial Measurement Unit (IMU). The Inertial Measurement Unit is used to measure the following CS/TMBS platform motions:

- Linear Acceleration
- Angular Acceleration
- Angular Rate

The requirement for a 6 degree-of-freedom motion sensor unit is satisfied by four two-axis angular rate sensor packages. The two-axis linear accelerometer packages are equally spaced from the center of the turret along the X and Y axis as shown in Figure 19. (This configuration is used for the purpose of measuring x, y, z, yaw, roll and pitch accelerations for the inertial safety interlocks without the need for the coordinate transformation required by a single package that is offset from the turret center.) This arrangement adds to the reliability of the safety interlocks and decreases response time.

The linear accelerometers used to derive linear and angular acceleration are mounted around the turret axis as shown in Figure 20. The eight Sunstrand Model QA-70 accelerometers are

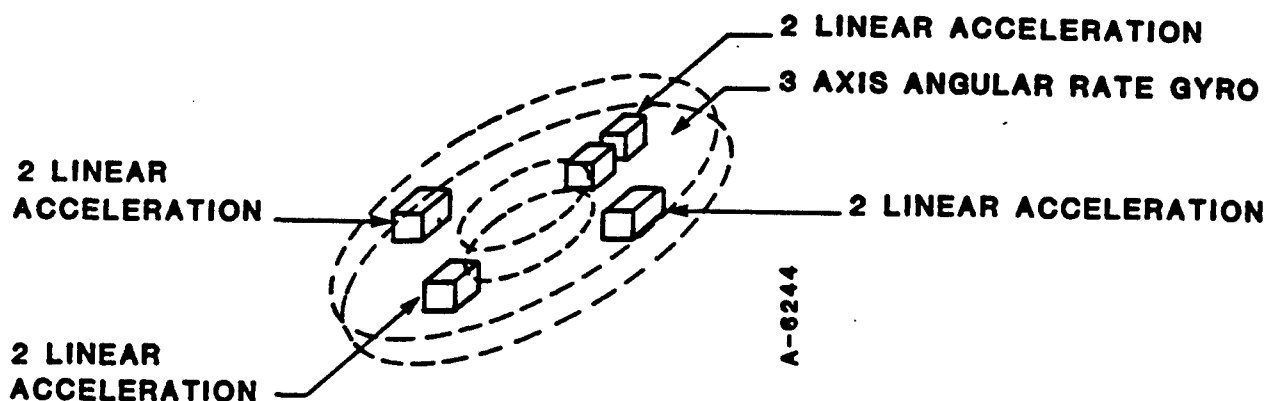


Figure 19. IMU Packages

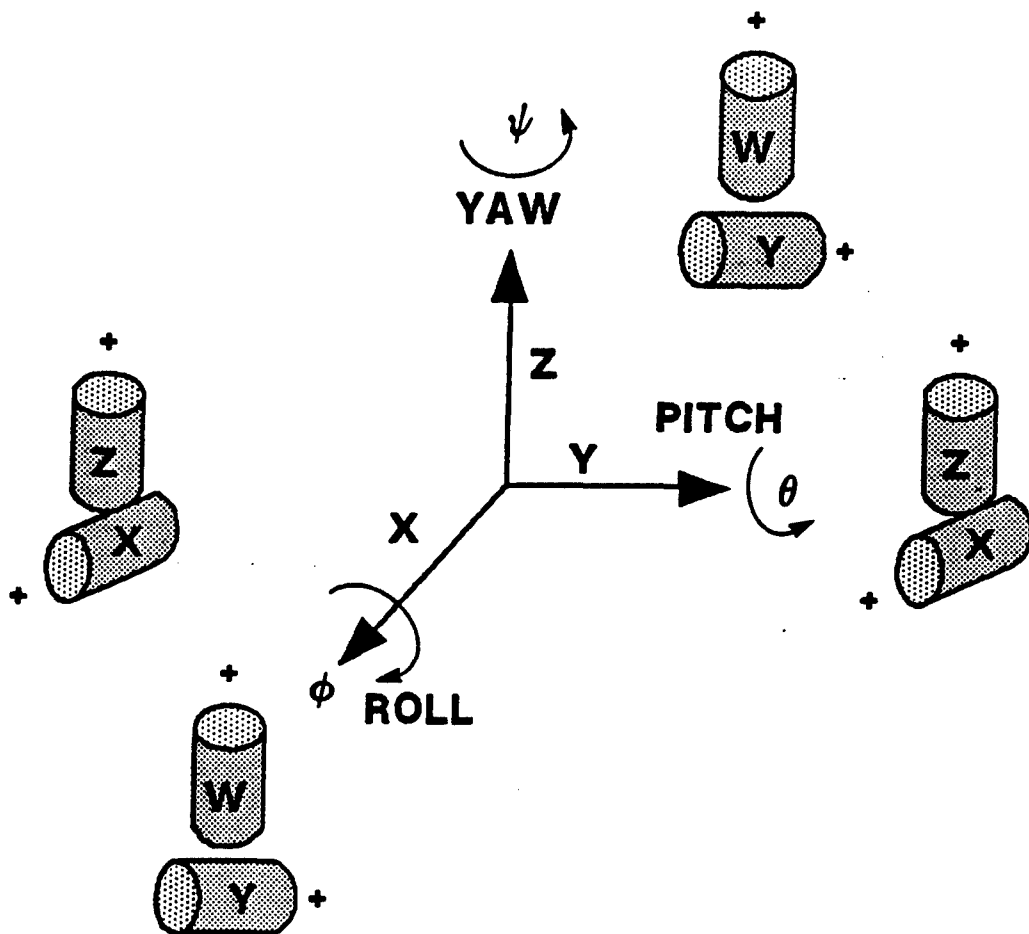


Figure 20. Acceleration Sensors

mounted in four two-axis mounting blocks located on the bottom of the CS/TMBS platform. These units are powered from a 15 volt power supply and produce a current proportional to acceleration.

Figure 21 shows in block diagram form how linear and angular accelerations are derived. Linear acceleration along the x, y, and z axes are derived by summing the outputs of opposing pairs of accelerometers. Angular accelerations are derived by taking the difference between opposing accelerometer outputs. The accelerometers are placed at a radius (approximately 60 inches) such that maximum operating linear and angular accelerations produce approximately the same output current.

The IMU chassis electronics contain circuits to produce voltages proportional to the combined magnitude of the individual linear accelerations. The three orthogonal acceleration signals are each squared, summed, then square rooted. The resultant signal is compared with a preset limit to determine if the acceleration in any direction exceeds a safe limit. If this limit is exceeded, the interlock system will activate the abort valves and shut the hydraulic power supply off. Similar circuits are used to detect if angular acceleration limits are exceeded.

The three linear, three angular and magnitude voltage outputs are digitized in order for the safety monitor and supervisor computers can monitor the IMU output. Each linear accelerometer has a self-test input to its internal torque motor. This test feature is used to verify IMU function and calibration before the CS/TMBS system can be energized.

The rate sensor assembly is a self-contained package built by Northrop (P/N 50830). This unit has three GI-G6 rate-integrating gyros mounted on three mutually orthogonal axes. Spinmotor and pickoff excitation are derived internally from the 28 VDC supply in the Power Supply Chassis. All capture electronics are included. This unit has a full scale range of 200 degrees/second. The outputs of the rate sensor package are digitized so that the safety monitor and supervisor computers can monitor angular rate. The IMU electronics also has a limit detector for angular rate that aborts the system if the limit is exceeded.

5.3.4. System operation. To operate the CS/TMBS, the following steps must be followed:

1. The electronics must be energized, both in the pit and on the control console. Turn the VT340 monitor on first, then press the SYSTEM POWER button on the console. The electronics in the pit are energized by flipping the toggle switch on the Interlock Control Box down, pressing the safety box (mounted on the wall behind the ICB) lever to ON and applying main power by turning circuit breaker #3 on in the box beneath the window to

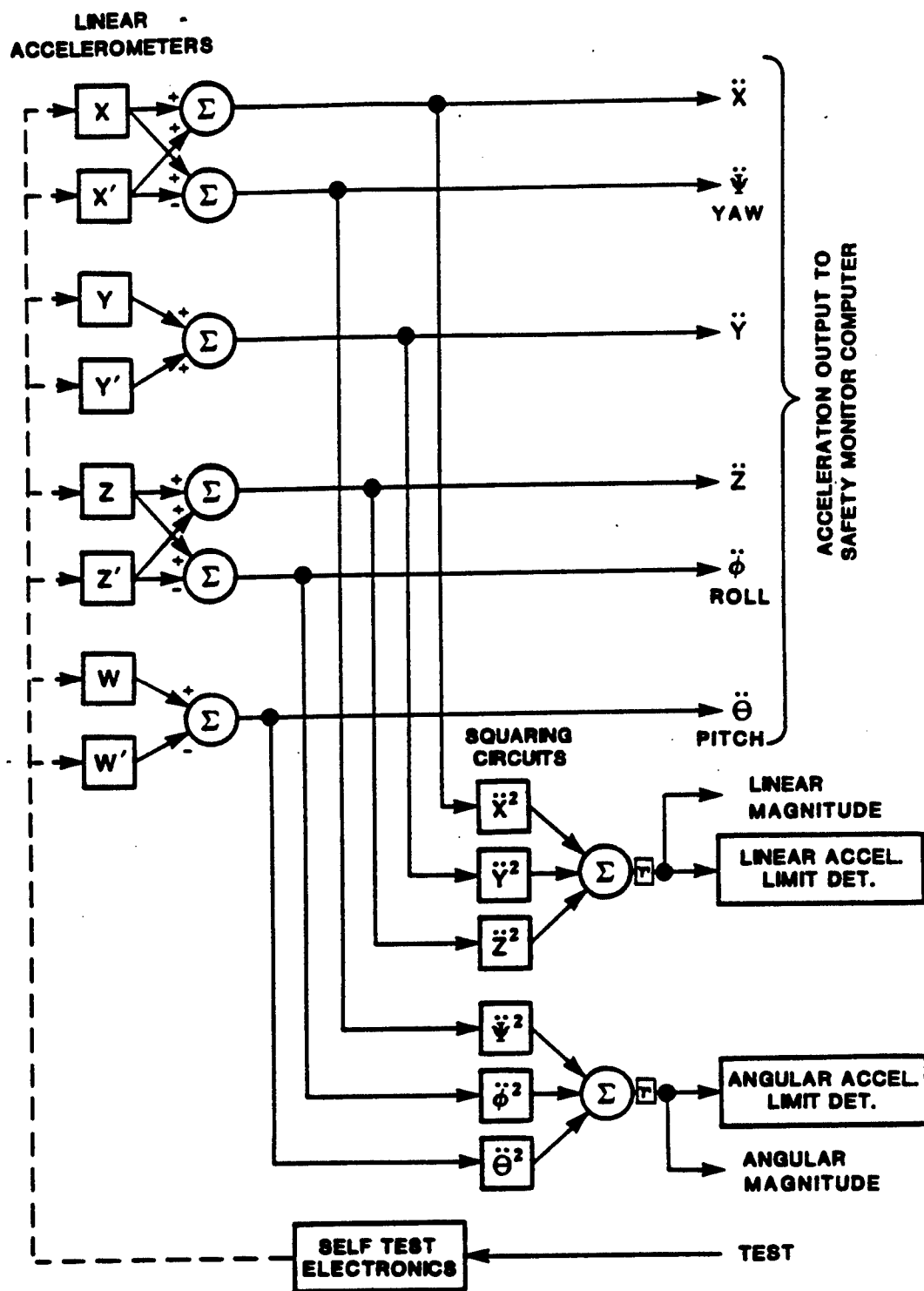


Figure 21. IMU Acceleration Electronics

the control room.

2. If you wish to do anything besides a "dry run", energize the hydraulics to 3000 psi and the required flow for a run (900 GPM for a 25 ton load, less for a lighter payload).

3. Upon power up, the CS/TMBS computer performs the safety monitor tests and offers a menu of:

- F1 -- RESET SAFETY
- F2 -- TIMEOUTS
- F3 -- VARIABLE RANGING

F1 will perform the same power up tests already performed. This is not necessary unless there was an error on power up.

F2 will enable the user to change the timeouts for some tests. This requires a password and should not be used at any time since they are properly set and stored in nonvolatile memory.

F3 will allow the variable ranging to be set for the D/A output variables and stored in non-volatile memory. This requires a password. After making changes, you will automatically proceed into the main menu.

Pressing any other key will proceed onto the main menu.

4. The Encoder Servo Processors (ESPs) must be booted up. To do this:

- a. Place the CS/TMBS in LOCAL mode (turn the key to LOCAL and press F5 if not in LOCAL mode already).
- b. Press F3 (DIAGNOSTICS).
- c. Press F1 (SELF TESTS).
- d. Enable the ESP tests by pressing 'Y' next to each box. Start the test by pressing F1 (START TESTS).
- e. Press F5 to return to the main menu. If there were any errors and the ESP is not cleared (there is still a red bar on the main menu), reset that ESP by pressing the red button on the specific card itself. Continue this step until the red bar is gone, indicating the ESPs are booted up.

NOTE: It seems to boot up more effectively if you determine which ESPs need resetting before the self tests and reset them. This can be done by looking at the force transducers (menu 13) and resetting the ESPs which show 0 lbs of force.

If there are any red bars on the INTERLOCK menu, correct the problem (i.e., - crane position, gate open, etc.) or refer to

the user's manual for more indepth problems.

5. If this is the first time for a run with a new payload on the platform, the user must let the CS/TMBS computer know the weight, inertia and center of gravity specifications. This is accomplished through the following steps:

- a. Enter LOCAL mode.
- b. Press F2 (SETUP).
- c. Press F3 (MODEL/PAYLOAD).
- d. Press F3 (PAYLOAD SETUP).
- e. Enter the principal moments, CG in vertical and the weight of the payload.
- f. Press F5 (RETURN MAIN MENU) to save these values in nonvolatile memory.

5.3.4.1. Local scenarios. To run a local scenario, perform the following:

1. Go to LOCAL mode if not already there.
2. Press F4 (DEFINE TEST) if a test scenario does not already exist. A password is required to define tests.

a. The menu now shows -

```
F1 -- LIMIT SETUP
F2 -- FREQ. RESPONSE
F3 -- GEN. SCENARIO
F5 -- MAIN MENU
```

F1 (LIMIT SETUP) -- This menu will define the position, rate and acceleration limits used in the pre-filter which will filter the input signals.

F2 (FREQ. RESPONSE) -- Will allow the user to use the six analog inputs on the back panel as the positional inputs for the six degrees of freedom. The user can enable or disable any or all of the six degrees of freedom.

F3 (GEN. SCENARIO) -- Allows the user to have the computer generate a scenario. There are 15 scenarios which can be reached by using the NEXT SCREEN or PREV SCREEN keys on the keyboard. Once the correct scenario is found, the user can specify the frequency, amplitude and phase for sine waves to be input for all six degrees-of-freedom.

3. Energize the hydraulic system. This is done by performing the following:

- a. Press F1 (HYDRAULIC ENABLE).
- b. Turn the System Keyswitch on the console to OFF.
- c. Select the servo valves to be used. This is done by typing 'Y' or 'N' next to each one to respectively enable or disable the valve.
- d. Press F5 (END CONFIGURATION).
- e. Turn the System Keyswitch to ON.
- f. Press the HYDRAULIC START button on the console.

This will enable the hydraulics and the CS/TMBS will rise to the liftoff position.

4. The platform must be moved to the mid-position level from the liftoff position. This is accomplished by pressing F5 (MAINTENANCE). This puts the CS/TMBS in maintenance mode. Press F3 (RUN MAINTENANCE) to enable motion. The MOTION ENABLE button is now lit. Pressing it (and holding it in until motion stops) will move the CS/TMBS to the mid-level position. Press F5 (MAIN MENU) to return to the main menu.

5. Press F4 (RUN TEST). Enter in the password, and the menu will now read:

F1 -- FREQ. RESPONSE
F2 -- LOCAL SCENARIO
F5 -- MAIN MENU

F1 (FREQ. RESPONSE) -- Allows the operator to start the frequency response test. The source of demand data will be the enabled analog input channels.

F2 (LOCAL SCENARIO) -- Allows the operator to choose from 15 pre-determined scenarios. This is done by pressing the NEXT SCREEN or PREV SCREEN key. Once the scenario is selected, press F4 (RUN SCENARIO) to start execution.

F5 (MAIN MENU) -- Returns the user to the main menu.

5.3.4.2. Maintenance mode. This mode will allow manual movement of the CS/TMBS. It can be operated as follows:

1. Go to LOCAL mode if not already there.
2. Energize the hydraulic system. This is done by performing the following steps:

- a. Press F1 (HYDRAULIC ENABLE).
- b. Turn the System Keyswitch on the console to OFF.
- c. Select the servo valves to be used. This is done by typing 'Y' or 'N' next to each one to respectively enable or disable the valve.
- d. Press F5 (END CONFIGURATION).
- e. Turn the System Keyswitch to ON.
- f. Press the HYDRAULIC START button on the console.

This will enable the hydraulics and the CS/TMBS will rise to the liftoff position.

3. Press F5 (MAINTENANCE MODE). The menu will now show:

F1 -- TOGGLE COMMAND
F2 -- TOGGLE SOURCE
F3 -- RUN MAINTENANCE
F5 -- RETURN MAIN MENU

F1 (TOGGLE COMMAND) -- Toggles the command between platform and direct cylinder control. This selection is shown in the CONTROL STATUS box on the screen.

F2 (TOGGLE SOURCE) -- Toggles the source of the input between the slide potentiometers on the console and the VT340 keyboard. This selection is also shown in the CONTROL STATUS box on the screen.

F3 (RUN MAINTENANCE) -- Once the desired source and commands have been selected, pressing this button will enable motion. The row of lights corresponding to the command selection (x, y, z, roll, pitch & yaw) or (cyl 1, 2, 3, 4, 5 & 6) will light up. The motion enable light will become active.

4. To move the CS/TMBS, do the following:

4a. In potentiometer mode, simply slide the potentiometers to the desired position and press the MOTION ENABLE button. The user must keep this button pressed for motion.

4b. In keyboard control, enter the positions in for motion via the keyboard and press the MOTION ENABLE button.

5.3.4.3. Remote simulation. This mode is where the CS/TMBS is driven from profile data (x, y, z, roll, pitch & yaw : positions, rates & velocities) received from the AD100 real

time computer. To operate in this mode:

1. Switch to REMOTE mode by pressing F5 (REMOTE MODE) and turning the system keyswitch to REMOTE.
2. Energize the hydraulic system. This is done by doing the following:
 - a. Press F1 (HYDRAULIC ENABLE).
 - b. Turn the System Keyswitch on the console to OFF.
 - c. Select the servo valves to be used. This is done by typing 'Y' or 'N' next to each one to respectively enable or disable the valve.
 - d. Press F5 (END CONFIGURATION).
 - e. Turn the System Keyswitch to ON.
 - f. Press the HYDRAULIC START button on the console.

This will enable the hydraulics and the CS/TMBS will rise to the liftoff position.

3. Start the simulation on the AD100 computer. When it is ready to communicate with the CS/TMBS, proceed to step 4.
4. Press F4 (SIMULATE). The CS/TMBS computer will ask for an identification number. This will correspond with the identification number the AD100 is sending over for this particular simulation. Enter the correct number and press carriage return.

5.3.4.4. Remote "dry-run" simulation. The CS/TMBS is inactive in this mode but still communicates with the AD100 real-time computer. It is a good way to ensure proper communication between the computers, as well as to check maximum and minimum values passed from the AD100 to the console. It works exactly the same as the REMOTE SIMULATION (Section 5.3.4.3.), but omit the step regarding energizing the hydraulics.

5.3.4.5. Compensate mode. Used only for modifying the CS/TMBS controller. **WARNING: Only to be used by qualified personnel.**

1. Go to LOCAL mode if not already there.
2. Energize the hydraulic system. This is done by doing the following this procedure:
 - a. Press F1 (HYDRAULIC ENABLE).
 - b. Turn the System Keyswitch on the console to OFF.

c. Select the servo valves to be used. This is done by typing 'Y' or 'N' next to each one to respectively enable or disable the valve.

d. Press F5 (END CONFIGURATION).

e. Turn the System Keyswitch to ON.

f. Press the HYDRAULIC START button on the console.

This will enable the hydraulics and the CS/TMBS will rise to the liftoff position.

3. Press F2 (SETUP).

4. Press F3 (MODEL/PAY).

5. Press F2 (ESP SETUP). This is a password mode. After entering the password, you are now in the ESP setup mode. Care should be taken when modifying any of the menus here and when saving the changes.

6. Press F3 (Toggle Compensate Mode). This will put the controller into compensate mode.

7. Type the number '160' into the top row of all six ESP screens. Then enter this as ESP command 241.

8. Enter the D-Matrix into the ESP screen. For a turret, it is stored in ESP Command 80. Type this to retrieve the D-Matrix. For all other payloads, type in the D-Matrix for position = 0.

9. Enter ESP Command 242. The CS/TMBS will rise to mid-position.

10. Enter ESP Command 242 again. This will save the D-Matrix into memory.

11. Enter ESP Command 240. This will put the CS/TMBS into full comp mode. Now any changes to the compensation will automatically be loaded into the current compensation.

5.3.5. Special Procedures Needed to Assure Safe Operations.

a. Assure the test subjects are apprised of all safety switches and communication equipment that they will operate. Also provide a thorough explanation of the purpose and duration of the test. The Human Use Committee shall approve all test scenarios prior to the use of test subjects.

b. Assure that personnel stay away from the simulator during the test.

c. Assure that the fire department/paramedics are aware of all tests in progress.

d. A Standard Operating Procedure (SOP) will be established for the simulator and surrounding area before any use of the simulator with test personnel. This SOP must be followed at all times.

5.4 System Safety Engineering

The methodology of MIL-STD-882B and AR-385-10 was used to identify and rank potential hazards associated with the Crew Station/Turret Motion Base Simulator.

Throughout the entire development of the CS/TMBS, all designs were made with safety in mind. All critical systems contain backups, whereas all other systems cannot cause damage if they fail. To ensure continued safety, a System Hazard Analysis has been conducted. Hazardous conditions and their respective hazard severity levels, probability levels and control measures are described in the report: "System Hazard Analysis of TACOM's Crew Station/Turret Motion Base Simulator", Report No. 13548.

A list of the hazards with higher degrees of severity and safeguards is presented below. For more detail, consult the "System Hazard Analysis of TACOM's Crew Station/Turret Motion Base Simulator" report.

HAZARD 1 - Structural Failure of Platform or Swivel Joints.

RAC - I E

SAFEGUARD 1 - The platform is designed to handle 50,000 lbs @5G with a factor of safety of 2.0. Other design criteria include factor of safety of 4.0 with worst case loads of 4G vertical and 3G arbitrary direction with simultaneous 10 rad/sec² accelerations. The swivel joint assemblies were stressed to four times the maximum strut load of 115,000 lbs. The remainder of the platform is stressed using 16 G's vertical, 12 G's lateral along x, and 12 G's lateral along y corresponding to the required 4G vertical and 3G arbitrarily directed accelerations. In addition, the platform endurance limit with a 50,000 lb turret installed is ± 2.25 G's in all directions at the 99.9% confidence level. Refer to the Contraves USA manual "TACOM PLATFORM FINITE ELEMENT ANALYSIS RESULTS," prepared under Contract DAAE07-87-C-R011.

HAZARD 2 - Failure of Hydraulic Actuators.

RAC - II E

SAFEGUARD 2 - The actuators are specifically designed by Moog

Corporation to the load tolerances set forth for this simulator. They meet all industry quality standards.

HAZARD 3 - Failure of Encoder Servo-Processor (ESP).

RAC - III D

SAFEGUARD 3 - Complete failure of an ESP will cause the CS/TMBS to lose control of that actuator. Each actuator has its own ESP card, so only one actuator would be affected. Loss of the ESP will cause a multi-bus lockup, which would tell the Safety Monitor Computer to shutdown the simulator immediately.

HAZARD 4 - Loss of data stored on the ESP.

RAC - IV E

SAFEGUARD 4 - The incorrect control loop may cause instability with the simulator. If so, the Inertial Measurement Unit will detect this and shut the simulator down within one second. Poor limits would in itself cause no problem, unless bad data was passed into the simulator. When running while using the AD-100 (the only mode of operation to be used with occupants in the payload), there is an extra set of limits and filters which run on the Supervisor Computer. Thus, no problem is posed in this scenario.

HAZARD 5 - Loss of servo valve.

RAC - IV C

SAFEGUARD 5 - Every actuator has three (3) servo-valves working together to control movement. If one servo was lost, the other two servos would compensate for the loss and no change would be noticed. If more than one servo went out at the same time (highly unlikely), loss of control of the actuator would occur, and the IMU or the Safety Monitor Computer would shutdown the simulator.

5.5 Health Hazard Assessment

Hearing protection will be required by all personnel in the simulator as well as operators near the simulator. This protection will come in the form of communication headsets, which will result in noise reduction for the personnel conducting the testing.

LIST OF REFERENCES

- 1) AR 385-10.
- 2) MIL-STD-882B.
- 3) Contraves USA Report #IM-27751, "INSTRUCTION MANUAL FOR TACOM," August 1990.
- 4) TACOM RDE CENTER Technical Report #13548, "SYSTEM HAZARD ANALYSIS OF TACOM's CREW STATION/TURRET MOTION BASE SIMULATOR," Alexander A. Reid, May 1992.

APPENDIX A

HYDRAULIC OIL
MATERIAL SAFETY SHEETS

MOBIL OIL CORPORATION MATERIAL SAFETY DATA BULLETIN

***** I. PRODUCT IDENTIFICATION *****

SUPPLIER: MOBIL OIL CORP.
 CHEMICAL NAMES AND SYNONYMS: PET. HYDROCARBONS AND ADDITIVES
 USE OR DESCRIPTION: HYDRAULIC OIL

MOBIL DTE 24

HEALTH EMERGENCY TELEPHONE: (212) 893-4411
 TRANSPORT EMERGENCY TELEPHONE: (800) 424-9300 (CHEMTREC)

***** II. TYPICAL CHEMICAL AND PHYSICAL PROPERTIES *****

APPEARANCE: ASTM 3 LIQUID ODDR: MILD PH: NA
 VISCOSITY AT 100 F, SJS: 160.0 AT 40 C, CS: 30.0
 VISCOSITY AT 210 F, SJS: 43.0 AT 100 C, CS: 5.0
 FLASH POINT F(C): 395(202) (ASTM D-92)
 MELTING POINT F(C): NA POUR POINT F(C): 0(-18)
 BOILING POINT F(C): > 600(316)
 RELATIVE DENSITY, 15/4 C: 0.865 SOLUBILITY IN WATER: NEGLIGIBLE
 VAPOR PRESSURE-MM HG 20C: < .1
 NA=NOT APPLICABLE NE=NOT ESTABLISHED D=DECOMPOSES
 FOR FURTHER INFORMATION, CONTACT YOUR LOCAL MARKETING OFFICE.

***** III. INGREDIENTS *****

WT PCT (APPROX)	EXPOSURE LIMITS MG/M3	SOURCES PPM (AND NOTES)
--------------------	--------------------------	-------------------------------

HAZARDOUS INGREDIENTS:
 NONE

OTHER INGREDIENTS:
 REFINED MINERAL OILS >95
 ADDITIVES AND/OR OTHER INGREDIENTS < 5

KEY TO SOURCES: A=ACGIH-TLV, A*=SUGGESTED-TLV, M=MOBIL, D=OSHA
 NOTE: LIMITS SHOWN FOR GUIDANCE ONLY. FOLLOW APPLICABLE REGULATIONS.

***** IV. HEALTH HAZARD DATA *****

EFFECTS OF OVEREXPOSURE: NOT EXPECTED TO BE A PROBLEM.

***** V. EMERGENCY AND FIRST AID PROCEDURES *****

EYE CONTACT: FLUSH WITH WATER.
 SKIN CONTACT: WASH CONTACT AREAS WITH SOAP AND WATER.
 INHALATION: NOT EXPECTED TO BE A PROBLEM.
 INGESTION: NOT EXPECTED TO BE A PROBLEM. HOWEVER, IF GREATER THAN 1/2 LITER(PINT) INGESTED, IMMEDIATELY GIVE 1 TO 2 GLASSES OF WATER AND CALL A PHYSICIAN, HOSPITAL EMERGENCY ROOM OR POISON CONTROL CENTER FOR ASSISTANCE. DO NOT INDUCE VOMITING OR GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON.

***** VI. FIRE AND EXPLOSION HAZARD DATA *****
FLASH POINT F(C): 395(202) (ASTM D-92)
FLAMMABLE LIMITS. LEL: .4 UEL: 7.0
EXTINGUISHING MEDIA: CARBON DIOXIDE, FOAM, DRY CHEMICAL AND WATER FOG.
SPECIAL FIRE FIGHTING PROCEDURES: FIREFIGHTERS MUST USE RECOMMENDED
PROTECTIVE EQUIPMENT.
UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE
NFPA HAZARD ID: HEALTH: 0, FLAMMABILITY: 1, REACTIVITY: 0

***** VII. REACTIVITY DATA *****
STABILITY (THERMAL, LIGHT, ETC.): STABLE
CONDITIONS TO AVOID: STRONG OXIDATION
INCOMPATIBILITY (MATERIALS TO AVOID): STRONG OXIDIZERS
HAZARDOUS DECOMPOSITION PRODUCTS: CARBON MONOXIDE.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

***** VIII. SPILL OR LEAK PROCEDURE *****
ENVIRONMENTAL IMPACT: REPORT SPILLS AS REQUIRED TO APPROPRIATE
AUTHORITIES. U. S. COAST GUARD REGULATIONS REQUIRE IMMEDIATE
REPORTING OF SPILLS THAT COULD REACH ANY WATERWAY INCLUDING
INTERMITTENT DRY CREEKS. REPORT SPILL TO COAST GUARD TOLL FREE
NUMBER 800-424-8802.
PROCEDURES IF MATERIAL IS RELEASED OR SPILLED: ADSORB ON FIRE RETARDANT
TREATED SAWDUST, DIATOMACEOUS EARTH, ETC. SHOVEL UP AND DISPOSE OF
AT AN APPROPRIATE WASTE DISPOSAL FACILITY IN ACCORDANCE WITH
CURRENT APPLICABLE LAWS AND REGULATIONS, AND PRODUCT
CHARACTERISTICS AT TIME OF DISPOSAL.
WASTE MANAGEMENT: PRODUCT IS SUITABLE FOR BURNING IN AN ENCLOSED,
CONTROLLED BURNER FOR FUEL VALUE OR DISPOSAL BY SUPERVISED
INCINERATION. IN ADDITION, THE PRODUCT IS SUITABLE FOR PROCESSING
BY AN APPROVED RECYCLING FACILITY OR CAN BE DISPOSED OF AT ANY
GOVERNMENT APPROVED WASTE DISPOSAL FACILITY. USE OF THESE METHODS
IS SUBJECT TO USER COMPLIANCE WITH APPLICABLE LAWS AND REGULATIONS
AND CONSIDERATION OF PRODUCT CHARACTERISTICS AT TIME OF DISPOSAL.

***** IX. SPECIAL PROTECTION INFORMATION *****
EYE PROTECTION: NO SPECIAL EQUIPMENT REQUIRED.
SKIN PROTECTION: NO SPECIAL EQUIPMENT REQUIRED. HOWEVER, GOOD PERSONAL
HYGIENE PRACTICES SHOULD ALWAYS BE FOLLOWED.
RESPIRATORY PROTECTION: NO SPECIAL REQUIREMENTS UNDER ORDINARY
CONDITIONS OF USE AND WITH ADEQUATE VENTILATION.
VENTILATION: NO SPECIAL REQUIREMENTS UNDER ORDINARY CONDITIONS OF USE
AND WITH ADEQUATE VENTILATION.

***** X. SPECIAL PRECAUTIONS *****
NO SPECIAL PRECAUTIONS REQUIRED.

Best Available Copy

***** XI. TOXICOLOGICAL DATA *****

---ACUTE---

ORAL TOXICITY (RATS): LD50: > 5 G/KG 0/10 RATS DIED AT THIS DOSAGE LEVEL. SLIGHTLY TOXIC (ESTIMATED) ---BASED ON TESTING OF SIMILAR PRODUCTS AND/OR THE COMPONENTS.

DERMAL TOXICITY (RABBITS): LD50: > 2 G/KG 0/10 RABBITS DIED AT THIS DOSAGE LEVEL. SLIGHTLY TOXIC (ESTIMATED) ---BASED ON TESTING OF SIMILAR PRODUCTS AND/OR THE COMPONENTS.

INHALATION TOXICITY (RATS): NOT APPLICABLE ---HARMFUL CONCENTRATIONS OF MISTS AND/OR VAPORS ARE UNLIKELY TO BE ENCOUNTERED THROUGH ANY CUSTOMARY OR REASONABLY FORESEEABLE HANDLING, USE, OR MISUSE OF THIS PRODUCT.

EYE IRRITATION (RABBITS): EXPECTED TO BE NON-IRRITATING. ---BASED ON TESTING OF SIMILAR PRODUCTS AND/OR THE COMPONENTS.

SKIN IRRITATION (RABBITS): EXPECTED TO BE NON-IRRITATING. ---BASED ON TESTING OF SIMILAR PRODUCTS AND/OR THE COMPONENTS.

***** XII. REGULATORY INFORMATION *****

TSCA INVENTORY STATUS: ALL COMPONENTS REGISTERED.

D.O.T. SHIPPING NAME: NOT APPLICABLE

D.O.T. HAZARD CLASS: NOT APPLICABLE

US OSHA HAZARD COMMUNICATION STANDARD: PRODUCT ASSESSED IN ACCORDANCE WITH OSHA CFR 1910.1200 AND DETERMINED NOT TO BE HAZARDOUS.

RCRA INFORMATION: THE UNUSED PRODUCT, IN OUR OPINION, IS NOT SPECIFICALLY LISTED BY THE EPA AS A HAZARDOUS WASTE (40 CFR, PART 261); DOES NOT EXHIBIT THE HAZARDOUS CHARACTERISTICS OF IGNITABILITY, CORROSIVITY, OR REACTIVITY, AND IS NOT FORMULATED WITH THE METALS CITED IN THE EP TOXICITY TEST. HOWEVER, USED PRODUCT MAY BE REGULATED.

THE FOLLOWING PRODUCT INGREDIENTS ARE CITED ON THE LISTS BELOW:

CHEMICAL NAME	CAS NUMBER	LIST CITATIONS
ZINC (ELEMENTAL ANALYSIS) (0.058 PCT)	7440-66-6	15

--- KEY TO LIST CITATIONS ---

1 = OSHA Z,	2 = ACGIH,	3 = IARC,	4 = NTP,	5 = NCI,
6 = EPA CARC,	7 = NFPA 40,	8 = NFPA 325M,	9 = DOT HMT,	10 = CA RTK,
11 = IL RTK,	12 = MA RTK,	13 = MN RTK,	14 = NJ RTK,	15 = MI 293,
16 = FL RTK,	17 = PA RTK,			

***** INFORMATION GIVEN HEREIN IS OFFERED IN GOOD FAITH AS ACCURATE, BUT WITHOUT GUARANTEE. CONDITIONS OF USE AND SUITABILITY OF THE PRODUCT FOR PARTICULAR USES ARE BEYOND OUR CONTROL; ALL RISKS OF USE OF THE PRODUCT ARE THEREFORE ASSUMED BY THE USER AND WE EXPRESSLY DISCLAIM ALL WARRANTIES OF EVERY KIND AND NATURE, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE IN RESPECT TO THE USE OR SUITABILITY OF THE PRODUCT. NOTHING IS INTENDED AS A RECOMMENDATION FOR USES WHICH INFRINGE VALID PATENTS OR AS EXTENDING LICENSE UNDER VALID PATENTS. APPROPRIATE WARNINGS AND SAFE HANDLING PROCEDURES SHOULD BE PROVIDED TO HANDLERS AND USERS. *****

PREPARED BY: MOBIL OIL CORPORATION
ENVIRONMENTAL AFFAIRS AND TOXICOLOGY DEPARTMENT, PRINCETON, NJ
FOR FURTHER INFORMATION, CONTACT:
MOBIL OIL CORPORATION, PRODUCT FORMULATION AND QUALITY CONTROL
3225 GALLOWES ROAD, FAIRFAX, VA 22037 (703) 849-3265

***** APPENDIX *****
FOR MOBIL USE ONLY: (FILL NO: RL10032A201) MHC: 1* 1* NA 0* 0* PPEC:
US33-044 APPROVE REVISED: 08/25/83

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APPENDIX B

TACOM SAFETY OFFICE

CONCURRENCE

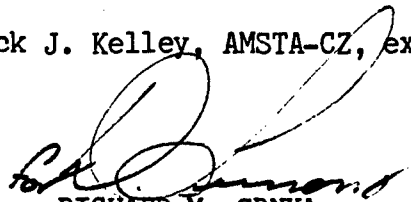
AMSTA-CZ (385-16)

27 August 1991

MEMORANDUM FOR C, Analytical & Physical Simulation Br (AMSTA-RYA)
ATTN: Mr. A. Reid

SUBJECT: Request for Safety Office Review of Safety Assessment Report and
System Hazard Analysis of TACOM's Crew Station/Turret Motion Base Simulator

1. Concurrence is provided for the Crew Station/Turret Motion Base Simulator (CS/TMBS) Safety Assessment Report and the System Hazard Analysis.
2. The POC for this action is Mr. Patrick J. Kelley, AMSTA-CZ, ext. 46310.


RICHARD M. GRNYA
Safety Director

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AMSTA-RYA (Mr. Reid)	15
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Director	
U.S. Materiel Systems Analysis Activity	1
ATTN: AMXSYP (Mr. Cohen)	
Aberdeen Proving Ground, MD 21005-5071	